STUDIES IN ELECTROCARDIOGRAPHY

A SERIES OF INVESTIGATIONS ON THE SIGNIFICANCE OF CERTAIN PHYSIOLOGICAL VARIATIONS IN THE STANDARD LIMB LEADS, UNIPOLAR LIMB LEADS AND MULTIPLE PRECORDIAL LEADS IN MAN

STUDIES IN ELECTROCARDIOGRAPHY

THESIS

presented to the University of Glasgow for the degree of

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by

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PART 1.

A COMPARATIVE STUDY OF THE UNIPOLAR AND BIPOLAR LEADS.

PART 1.

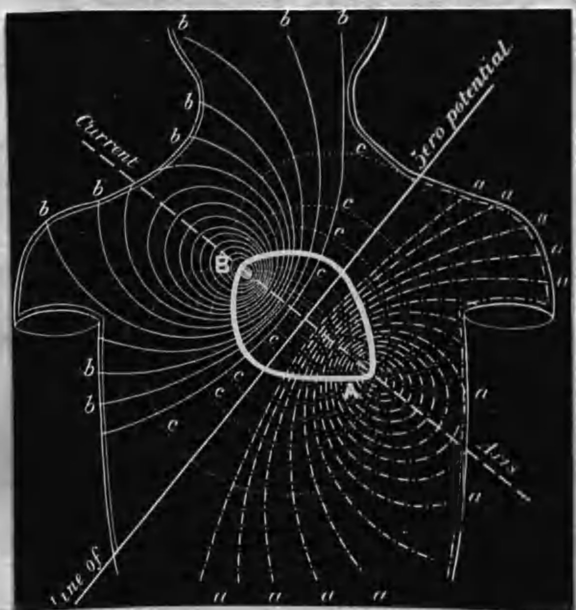
A Comparative Study of the Unipolar and Bipolar Leads.

SECTION 1.

Historical review.

In no realm of medicine is a historical review more revealing and informative than in clinical electrocardiography. The work of the early pioneers in the subject, far from being superseded by recent developments, still remains the basis upon which the modern views on unipolar leads, including the chest leads, are founded. Though much electrocardiographic information has been derived empirically, and despite the tendency to employ a purely descriptive analysis of tracings, yet from its inception the science of electrocardiography has been closely related to certain fundamental mathematical premises, some understanding of which is necessary for a proper appreciation of the method. These principles are included in the following survey.

The human electrocardiogram was first recorded by Waller (1887), using the capillary electrometer and a chest lead with one electrode placed over the precordium and the other on the back. He also described the appearances of a variety of other leads, including precordium to each of the limbs, mouth to precordium and to each of the limbs, and the six possible combinations of two limbs. Some of these leads he found to be "favourable" to the registering of potential differences, while others were "unfavourable", and in particular he noted that there was no demonstrable potential difference between the two feet. Shortly afterwards (Waller, 1889) he gave a theoretical interpretation of the electrical activity of the heart in which he supposed that the excitatory process in the ventricles commenced at the apex and spread to the base. A line drawn in this direction represented the electrical axis of the heart, and another line at right angles to it drawn through the centre of the heart ("equatorial line") was a line of zero potential dividing the body into two parts, positive above it and to the right, and negative below it and to the left. Isopotential surfaces were then constructed as shown in the diagram (fig. 1).



a,a... are equipotential lines surrounding A.

b,b... are equipotential lines surrounding B.

c,c... are lines of current diffusion.

Fig. I

After Waller , I889.

Leads in which the electrodes were on opposite sides of the equator (such as precordium to right arm) were "favourable" or "strong" leads in so far as they tended to show large differences in potential, while leads in which the electrodes were on the same side of the equator (such as precordium to left arm or left leg) were "unfavourable" or weak leads in so far as they tended to show small differences in potential. It is obvious from this construction, as Wilson (1930) has pointed out, that Waller was familiar with the mathematical laws regarding the distribution of potential differences in volume conductors. Furthermore, though his assumption regarding the direction of the electrical axis was diametrically wrong and was in fact corrected in his later articles (Waller, 1913 b, c), his distinction between "favourable" and "unfavourable" leads was remarkably akin to modern ideas on the general relationship between the CR, CL, and CF types of chest leads.

A brief account of Waller's (1913 c) mathematical treatment of the electrical axis is not out of place as it has been stated (Dieuaide, 1921) that the only difference between his method of calculation and that of Einthoven et al.(1913) is that their respective angles "α" are complementary. This latter fact is indeed so, but there are also other important differences. Waller always regarded his differentiation between strong and weak leads as being of the utmost importance and in general he employed a five lead system, as follows:-

Transverse Lead (right arm to left arm): Lead 1.

Right Inferior Lead (right arm to foot): Lead 11.

Left Inferior Lead (left arm to foot) : Lead 111.

Right Superior Lead (mouth to right arm): Lead 1V.

Left Superior Lead (mouth to left arm): Lead V.

The strong leads were 1, 11 and V, and the weak leads 111 and 1V (fig. 2).

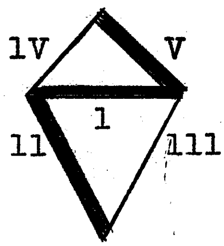


Fig. 2.

1. Transverse.
11. Right lateral.
111. Left lateral.
1V. Right superior.
V. Left superior.

After Waller, 1913 (c).

He then considered two opposed triangles (fig. 3), a superior one MRL and an inferior one FRL, with the heart at the mid-point V of their common base. The superior one was isosceles with a right angle at M (i.e. $MV = RV = \frac{1}{2}RL$); the inferior one was also isosceles with its base equal to its altitude (i.e. $VF = 2RV = RL$).

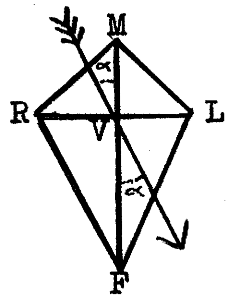


Fig. 3

After Waller, 1913 (c).

By a simple trigonometrical construction he then demonstrated that the direction of the electrical axis could be calculated above and below the heart according to the general formula:

$$\tan\alpha = \cot\theta \frac{S - W}{S + W}$$

where α is the inclination of the axis with the vertical, $\theta = \frac{1}{2}$ the angle at M or F, and S the strong lead and W the weak lead. For the superior triangle therefore

$$\tan\alpha = \frac{L - R}{L + R} \text{ or } \frac{V - 1V}{V + 1V}$$

while for the inferior triangle

$$\tan\alpha = 2\frac{R - L}{R + L} \text{ or } 2\frac{11 - 111}{11 + 111}$$

It is readily seen that though the apices of the lower triangle are the same as those of Einthoven's equilateral triangle, the other postulates are quite different.

Waller also proposed systems of "thoracic leads" for calculating the electrical axis in the sagittal and horizontal planes. For the sagittal plane (fig. 4) there were the superior leads, mouth to precordium and mouth to back, and the inferior leads, back to foot and precordium to foot.

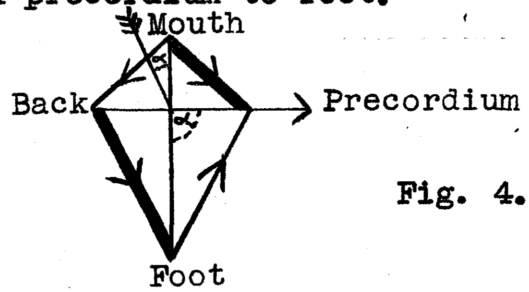


Fig. 4.

After Waller, 1913 (c).

The triangles were identical in form to those for the frontal plane and the calculations were also similar i.e. for the superior triangle the formula

$$\tan\alpha = \frac{S - W}{S + W}$$

was employed, and for the inferior triangle the formula

$$\tan\alpha = 2\,\frac{S - W}{S + W}$$

In the horizontal plane (fig. 5), a symmetrical system of four leads round the chest was suggested, namely, precordium to left and right sides, and back to left and right sides.

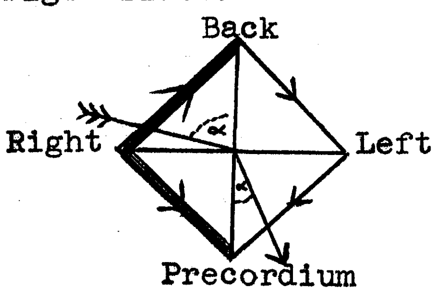


Fig. 5.

After Waller, 1913 (c).

The triangles in this case were identical right-angled isosceles triangles and the calculation in each case was therefore from the formula

$$\tan\alpha = \frac{S - W}{S + W}$$

As might be expected he found that there was a considerable difference in the angle α as calculated from the two triangles of each pair.

In their early investigations with the capillary electrometer Einthoven and de Lint (1900) also used various chest leads, and they too found that the lead which consistently gave the largest deflections was that between the apex and the right arm or right shoulder. After much experimental work, however, Einthoven (1912) finally adopted the system of the three standard leads 1, 11 and 111 and outlined a mathematical relationship between these leads. This fundamental theory of the equilateral triangle with the principle underlying it was more fully described in a subsequent article, (Einthoven et al.1913). Briefly the exposition was as follows (fig. 6):-

If a potential difference exists between two points very close together at the centre H of an equilateral triangle RLF in a homogeneous conducting plate, and if an arbitrary distance pq is laid out along the line joining the negative to the positive pole, then the resultant potential difference produced between any two apices of the triangle is proportional to the projection of pq on the side of the triangle joining them.

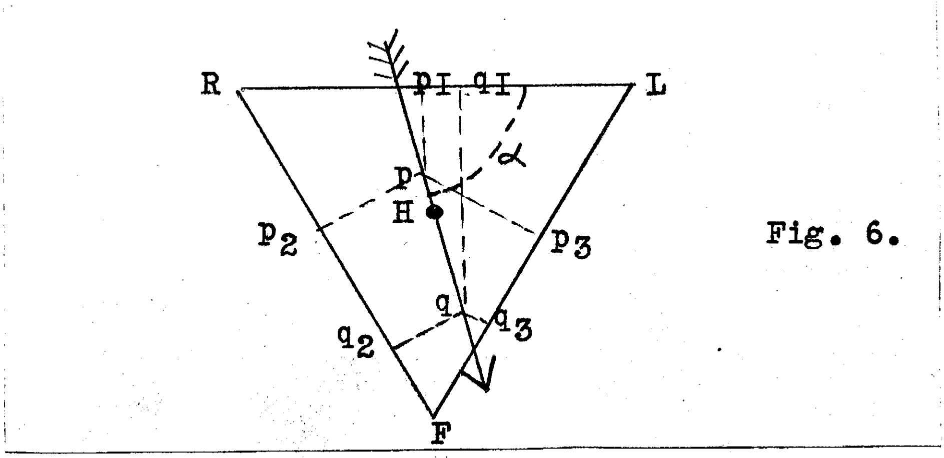


Fig. 6.

Let pq = E, $p_1q_1 = e_1$, $p_2q_2 = e_2$ and $p_3q_3 = e_3$

Then $e_1 = E\cos\alpha$ ....(1)

$e_2 = E\cos(\alpha - 60°)$ ....(2)

$e_3 = E\cos(120° - \alpha)$ ....(3)

$e_3 = e_2 - e_1$ ....(4)

The differences of potential between the apices of the triangle are in proportion to $e_1 : e_2 : e_3$.

To determine α, by solution of these equations,

$$\tan\alpha = \frac{2e_2 - e_1}{e_1\sqrt{3}} \qquad ....(5)$$

$$\text{or} \quad \tan\alpha = \frac{2e_3 + e_1}{e_1\sqrt{3}} \qquad ....(6)$$

$$\text{or} \quad \tan\alpha = \frac{e_2 + e_3}{(e_2 - e_3)\sqrt{3}} \qquad ....(7)$$

E can then be determined from equations (1), (2) or (3).

After Einthoven et al.(1913).

These projections (e_1, e_2, e_3) can be expressed in terms of the original magnitude E and the angle α which this makes with the side RL of the triangle, as in equations (1), (2) and (3), and they are also related to each other as in equation (4). By simultaneous solution of the appropriate equations, the value of α can be determined from formula (5), (6) or (7) when any two of the variables e_1, e_2 and e_3 are known, and E can then be calculated from one of the first three equations. The value of E is termed the "manifest potential" and the angle α is the inclination of the "electrical axis" to the horizontal. It is emphasised that the manifest potential is only a small fraction of the actual potential difference existing at the centre of the triangle, and varies directly in magnitude with the distance between the positive and negative poles of the latter. It really represents the maximum potential difference which can be produced between any two apices of the triangle by the central potential difference, and this of course occurs when the electrical axis is parallel to the side of the triangle joining these two apices. The application of this theory to the analysis of the three standard leads in man involves certain suppositions which are quite clearly stated. Thus the three limb electrodes are considered to be equidistant from each other at the apices of an equilateral triangle in the frontal plane of the body, and the heart is represented as a point also in this plane at the centre of the triangle and therefore equidistant from each of the apices. The body, of which the frontal plane is a section, is treated as a homogeneous volume conductor and the resistances between the heart and each of the apices are therefore equal. These suppositions, though they are not absolutely true, are sufficiently accurate for all practical purposes. It is also explained that a potential difference acting at an angle to the frontal plane has an effect in this plane proportional to the cosine of the angle, and consequently if it is perpendicular to the frontal plane it has no influence on the three leads.

Largely as a consequence of this exposition, the three standard limb leads 1, 11 and 111 were adopted for clinical work and the various chest leads were discarded. Certain types of precordial leads however were still employed for special purposes, particularly by Lewis and his associates (Lewis 1910, Drury and Iliescu 1921, Lewis et al. 1921a,b) in their demonstrations of auricular flutter and fibrillation in man, and by Cohn and Raisbeck (1922a,b) in their study of the effect of the position of the heart on the human electrocardiogram.

Meantime Wilson and Herrmann (1920) in the course of their work on intraventricular block had been impressed by the fact that potential differences of much greater magnitude could be recorded in the immediate vicinity of the heart than at a distance from it, and that in certain leads where both electrodes were placed on the chest, the pattern of the electrocardiogram appeared to be mainly determined by the position of the electrode which was nearer to the heart. These observations led to a preliminary discussion of the laws relating to the distribution of potential differences in volume conductors and their application to the cardiac action potentials in the human body (Wilson et al.1926).

Some time later a full report was given by Wilson (1930) in which, after explaining in detail the postulates of Einthoven et al.(1913), he also furnished the mathematical proof of the theory which, though obviously known to them, had not actually been included in their original exposition. In addition, he described some illustrative experiments on an artificial model representing an equilateral triangle with an inductorium at its centre laid out in a large pan containing an electrolytic solution. The results were in accordance with the theory. It was also shown that when the body is considered as a volume conductor and the resultant E.M.F. of the heart as a "dipole" at its centre, the potential produced at any point in the body by the heart varies inversely with square of the distance of that point from the heart. Leads in which one electrode is placed over the precordium and the other at a distance from the heart record a curve therefore which represents to all intents and purposes the potential variations of the precordial electrode. Such leads were termed "semi-direct" leads and their similarity to direct leads of the kind used by Lewis and Rothschild (I9I5), in which one electrode was in contact with the heart and the other at a point on the chest wall remote from it, was emphasised. In further explanation of Einthoven's system, it was pointed out (Wilson et al. I93Ia) that the "Einthoven equation"

Lead II= Lead I+ Lead III

does not depend on the equilateral triangle theory, but is purely a consequence of the manner in which the leads are taken. Provided the method of standardisation is correct, the same relationship would hold between three leads taken from any three points on the body in the same order. These leads would not of course necessarily satisfy the assumptions of the equilateral triangle theory and could not therefore be analysed by that scheme.

These considerations were the prelude to an important article published about the same time (Wilson et al. I93Ib) in which it was demonstrated that bipolar chest leads could be freed from the influence of the distant electrode and thereby rendered "unipolar".

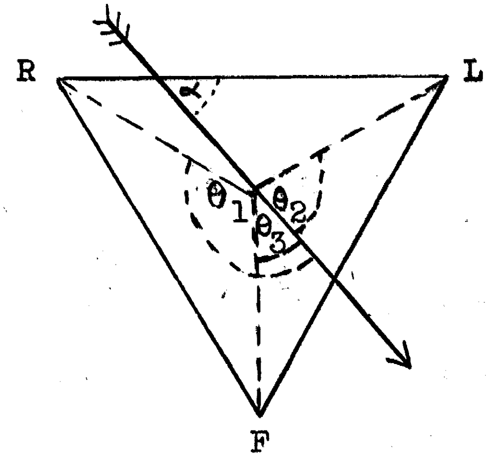


Fig. 7.

After Wilson et al., 1931b.

Their reasoning was as follows (fig. 7) :-

It can be shown (Wilson, 1930) that under the conditions of the equilateral triangle theory, the resulting potential at any of the apices of the triangle is directly proportional to the cosine of the angle between the electrical axis and the line joining the centre of the triangle to that apex, i.e.,

$$VR = A\cos\theta_1 \qquad \text{(1a)}$$

$$VL = A\cos\theta_2 \qquad \text{(1b)}$$

$$VF = A\cos\theta_3 \qquad \text{(1c)}$$

where A is a constant proportionality factor. It can also be shown that (Einthoven et al, 1913)

$$e_1 = VL - VR = E\cos\alpha \qquad \text{(2a)}$$

$$e_2 = VF - VR = E\cos(\alpha - 60^\circ) \qquad \text{(2b)}$$

$$e_3 = VF - VL = E\cos(120^\circ - \alpha) \qquad \text{(2c)}$$

$$\therefore E\cos\alpha = A(\cos\theta_2 - \cos\theta_1) \quad \ldots\ldots\ldots\ldots\ldots (3a)$$

$$E\cos(\alpha - 60^\circ) = A(\cos\theta_3 - \cos\theta_1) \quad \ldots\ldots\ldots (3b)$$

$$E\cos(120^\circ - \alpha) = A(\cos\theta_3 - \cos\theta_2) \quad \ldots\ldots\ldots (3c)$$

But,

$$\theta_1 = 210^\circ - \alpha, \text{ and } \theta_2 = 30^\circ + \alpha \text{ and } \theta_3 = 90^\circ - \alpha$$

Substituting in 3a,

$$E\cos\alpha = A\left[\cos(30^\circ + \alpha) - \cos(210^\circ - \alpha)\right] = A\sqrt{3}\cos\alpha$$

$$\therefore A = \frac{E}{\sqrt{3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

By substitution in 1c,

$$VF = \frac{E}{\sqrt{3}}\cos(90^\circ - \alpha) = \frac{E}{\sqrt{3}}\sin\alpha \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

This can be expressed in terms of e_2 and e_3, for

$$e_2 + e_3 = E\left[\cos(\alpha - 60^\circ) + \cos(120^\circ - \alpha)\right]$$

$$= E\sqrt{3}\sin\alpha$$

$$\therefore \frac{e_2 + e_3}{3} = \frac{E}{\sqrt{3}}\sin\alpha$$

$$\therefore VF = \frac{e_2 + e_3}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6a)$$

Similarly it can be shown that

$$VR = -\frac{e_1 + e_2}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6b)$$

$$\text{and} \quad VL = \frac{e_1 - e_3}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6c)$$

If e_4 = the potential in a precordial or any other lead (VP) paired with VF,

then $VP - VF = e_4$.

$$\therefore VP = e_4 + \frac{e_2 + e_3}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Stated in words, when an exploring electrode is paired with an electrode on one of the limbs, the actual potential of the exploring electrode can be found by algebraic addition of the recorded potential and the potential of the limb as calculated from the recorded potentials of the appropriate standard leads by one of the formulae 6a, 6b or 6c.

These principles were first applied by Wilson et al. (1932a) in their study of human bundle-branch block, in which they were able to show by means of serial precordial leads that the common type of bundle-branch block in man was left and not right as had previously been supposed. Incidentally, it was also pointed out that this new idea was in accord with the results of direct stimulation of the exposed human heart as observed by Barker et al. (1930). They also employed them in their early study of coronary thrombosis (Wilson et al., 1932b).

One further step in the evolution of "unipolar" leads was now required, namely the direct registration of such curves. This was soon forthcoming in the concept of the "central terminal" (Wilson et al., 1934a). In this article it was shown that if any three electrodes are connected through equal resistances to a central terminal, then the potential of this terminal is equal to the mean potential of the three electrodes. Furthermore, if the three electrodes chosen are on the right arm, left arm and left leg respectively (i.e. at the apices of Einthoven's triangle), and if the equilateral triangle theory is valid, then the potential of the central terminal is zero. Leads in which an exploring electrode is paired with the central terminal can then be considered unipolar in so far as they record only the potential fluctuations of the exploring electrode.

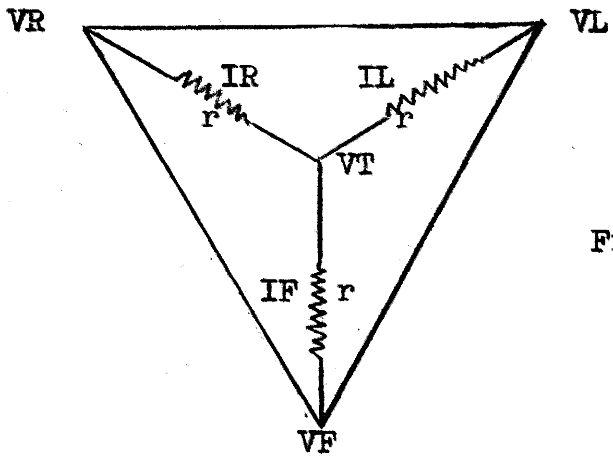


Fig. 8

The proof is quite simple (fig. 8). Let VR, VL, VF and VT be the potentials at the right arm, left arm, left leg and central terminal respectively; let the resistances r between each of the three extremities and the central terminal be equal; let IR, IL and IF be the currents flowing between the central terminal and the right arm, left arm and left leg respectively. Then by ordinary electrical principles,

$$VR - VT = rIR$$

and $$VL - VT = rIL$$

and $$VF - VT = rIF$$

On addition

$$(VR - VT) + (VL - VT) + (VF - VT) = r(IR + IL + IF) = 0.$$

(by Kirchkoff's Law)

$$\therefore VT = \frac{VR + VL + VF}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1).$$

But according to the equilateral triangle theory (Wilson et al, 1931b),

$$VR = -\frac{e_1 + e_2}{3}$$

and $$VL = \frac{e_1 - e_3}{3}$$

and $$VF = \frac{e_2 + e_3}{3}$$

$$\therefore VR + VL + VF = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

From equations (1) and (2)

$$VT = 0$$

Also, the direction of the electrical axis can be calculated from the formula,

$$\tan\alpha = \frac{\sqrt{3}\ VF}{VL - VR}$$

Experiments with the central terminal were performed on the artificial model previously described (Wilson, 1930) and again the results were in agreement with the theory.

For practical purposes a system containing a vacuum tube was used, the string galvanometer being connected to the plate circuit, and the central terminal and exploring electrode to the input circuit. This had the advantage of eliminating the condenser-like effect of the high skin resistance. It was also explained that since the accuracy of the method depended mainly on the equality of the resistances between the heart and the central terminal in each of its branches, and since differences in skin and internal body resistance were likely to occur, the external resistances (r) in these branches, as well as being equal, should also be large in comparison with the largest body resistance between any two of the electrodes. Large resistances of 25,000 ohms were therefore used in their earliest experiments, but as this made the apparatus too sensitive to stray alternating current interference, resistances of 5,000 ohms were ultimately chosen. Unipolar leads were recorded in this way from each of the limbs (VR, VL and VF) and from the precordium (V_1, V_2, V_3, V_4, and V_5) and from the ensiform process (VE). This system of leads was used by Wilson and his associates in their important investigations on human bundle-branch block (Wilson et al, 1934b, c) in which as Hill (1950) states, "the death knell of the old concepts was sounded"; and also in their work on experimental myocardial infarction (Wilson et al, 1934d, Johnston et al, 1935, Wilson et al, 1935a, b) on which the "window" idea of infarction was based. It was also shown by

Wilson et al. (1934e) that in the dog, the left ventricular cavity was negative during the whole of the QRS interval, and the right ventricular cavity was also negative during most of that time though there was usually a short initial period of positivity which might be explained by prior activation of the left side of the septum. They further stated that "when the exploring electrode is placed on the precordial surface, its potential is conspicuously different from that of the nearest portion of the ventricular cavity only during the period when the excitation wave is spreading outward through the subjacent ventricular wall". In an epicardial lead therefore, an initial Q wave if present is due to negative cavity potential and indicates relatively late excitation of the endocardium under the electrode; the positive R wave occurs during the passage of the excitation wave from the endocardium to the epicardium under the electrode; and an S wave if present again reflects the negativity of the cavity.

Many years later, the principles upon which the interpretation of the origin of the QRS deflections in unipolar electrocardiograms is based were restated more explicitly by Wilson et al. (1944) from whom the following quotation is taken.

"The resting cardiac muscle fiber is

surrounded by a "membrane" which has a very low electrical conductivity. Across this membrane there is an electromotive force which makes its inner surface strongly negative in comparison with its outer surface. The passage of the excitatory process along the fiber is associated with a sudden and very great increase in the conductivity of the resting membrane and a sudden decrease in the electromotive force (Cole and Curtis, 1939), in other words, with the sudden development of a short circuit between the inside and the outside of the fiber. Current flows out of the resting part of the fiber adjacent to the short circuit and re-enters the fiber through the short-circuited region. The effect in the medium outside the fiber is the same as if the cardiac impulse were immediately preceded by the positive pole, and accompanied by the negative pole of a battery. In other words, we may say that, across the boundary between active and resting muscle, there is an electromotive force which makes the potential of points towards which the excitation wave is advancing positive, and the potential of points which lie behind it negative".

As has recently been emphasised by Hill (1950), this conception is identical with the "doublet" hypothesis independently formulated by Craib (1930) as a result of his classical researches on the electrocardiogram.

Simultaneously with the demonstration by Wilson et al. (1932a) of the value of precordial leads in bundle-branch block, Wolferth and Wood (1932) had introduced a chest lead for use particularly in cases of myocardial infarction where the standard limb leads had failed to show any abnormality. This lead which they termed Lead 1V was an antero-posterior chest lead, with the exploring electrode placed in the vicinity of the cardiac apex and the other in the region of the angle of the left scapula. Subsequently, in their studies of myocardial infarction in the dog (Wood and Wolferth, 1933), and in man (Wood et al., 1933) they also employed two other leads, namely, precordium to left leg (Lead V) and angle of left scapula to left leg (Lead Vl). As these leads were taken in the same order as the standard leads 1, 11 and 111, they also satisfied the equation Lead V = Lead 1V + Lead Vl, but as Kossmann (1936) pointed out, they could not be analysed by the equilateral triangle method since they did not satisfy the requirements of this theory, the apical electrode in particular being so much nearer the heart than the other electrodes. Incidentally, it is of interest to note that leads 1V, V and Vl are practically identical to the original antero-posterior and two inferior leads in the sagittal plane used by Waller (1887 and 1913c).

The introduction of Lead 1V, however, stimulated a general interest in chest leads and a large number of observations on their use soon followed (Katz and Kissin, 1933, Hoffman and Delong, 1933, Goldbloom, 1934, and Master, 1934). In the main, various modifications of Lead IV and Lead V were employed, the precordial electrode being paired with an electrode on the back or the left leg, but a precordial electrode paired with the right arm also had its advocates (Roth, 1935), on the grounds that such a combination yielded the maximum deflections in the resulting electrocardiogram. Further confusion existed with regard to the polarity of the chest leads, for some workers adhered to the original technique in which an upward deflection of the string represented relative negativity of the chest electrode, while others preferred to reverse the connections so that an upward deflection represented relative positivity of the chest electrode. This latter method, though at variance with accepted physiological procedure (Hill, 1950), yielded precordial curves which bore a general resemblance to the familiar standard lead patterns. It soon became obvious that some degree of uniformity was essential for practical routine purposes and this was achieved by a joint committee of the American Heart Association and the Cardiac Society of Great Britain and Ireland (1938a,b, 1939). The new polarity was accepted, by which an upward deflection of the string represented relative positivity of the chest electrode; a standard size of exploring electrode was recommended; and the location of a single apical precordial lead was fixed, to be termed Lead lV and further defined as R, L, F, B or T, depending on whether the second connection was made to the right arm, left arm, left leg, back or central terminal respectively. In addition, the American Heart Association (1938) issued a supplementary report on its own behalf, which was later amplified (American Heart Association, 1943b), standardising the positions of a series of multiple precordial leads. These were numbered 1 to 6 and were sited as follows:-

1. Right margin of the sternum in the 4th interspace.
2. Left margin of the sternum in the 4th interspace.
3. Midway between points 2 and 4.
4. Left mid-clavicular line in the 5th interspace.
5. Left anterior axillary line at the same level as 4.
6. Left mid-axillary line at the same level as 4.

These leads were designated CR, CL or CF depending on whether the remote electrode was placed on the right arm, left arm or left leg respectively; the single letter V was reserved for such leads when they were recorded by the central terminal technique.

Though the nomenclature had thus been clarified, the relative merits of the various types of lead remained a matter of contention. Bipolar leads of the CR or CF type were most generally favoured in preference to the unipolar leads partly because comprehensive comparative studies had not yet been made, and partly because no special apparatus was required for their registration (Wood and Selzer, 1939). Objections were also maintained against the central terminal system, however, on theoretical and experimental grounds by Wolferth et al. (1941), Wolferth and Livezey (1944), and Katz (1946). In particular, Wolferth and Livezey (1944), having carried out certain tests of their own, rejected as invalid the results of various immersion procedures (Eckey and Fröhlich, 1938, Burger, 1939) which had been adduced by Wilson et al. (1944) in support of their statement "that the largest potential variations of the central terminal do not ordinarily exceed 0.3 millivolt", and they also averred that in their experience, an electrode placed over the spine of the right scapula was more uniformly indifferent than the central terminal. The immersion experiments referred to above consisted briefly in placing a subject in a large tub filled with distilled or tap water, and surrounding him with a metal screen, direct contact between subject and screen being suitably prevented. Under these conditions, a potential difference could be demonstrated between the screen and the water inside it, but not between the screen and the water outside. The potential of the screen was then compared with that of the central terminal and the difference was found to be no greater than 0.3 millivolt. In a final discussion of these and other experiments pertaining to the theory of unipolar leads, Wilson et al. (1946) concluded that for practical purposes, the Einthoven triangle theory and the doublet hypothesis could be considered valid and that, to quote, "So far as we are able to judge from our experience with the central terminal, its potential is ordinarily close to the average of that of the body surface".

Meanwhile, two important modifications in unipolar technique had been introduced by Goldberger (1942a,b).

(1) Because of the fairly high skin-electrode resistances normally encountered, he considered that the external 5,000 ohm resistances in the branches of the central terminal were unnecessary for the recording of either precordial or extremity potentials. In the latter case, however, if a terminal of this type were employed, an additional electrode had to be placed on the limb whose potential was being registered, in contrast to the original Wilson procedure where the

same electrode could be used for both the terminal and exploring connections. It was recommended that the additional electrode be placed just above the elbow or the knee as required. Unipolar precordial and extremity leads taken by the two methods were said to be identical.

(2) The principle of augmentation of the extremity potentials was described. Goldberger stated that by breaking the central terminal connection to the extremity whose potential was to be recorded, but otherwise proceeding as usual, deflections of the same form as in ordinary unipolar limb leads but one half greater in amplitude were obtained. These he termed "augmented" unipolar extremity leads or potentials and he named them aVR, aVL and aVF to distinguish them from the ordinary or unaugmented unipolar limb leads VR, VL and VF. As he pointed out, deflections in these augmented leads should be measured in millimetres, since their actual amplitude in millivolts is less by one third, the sensitivity of the galvanometer not having been altered. He also stated that as far as the resulting augmented curves were concerned, it made no difference whether the original Wilson terminal with 5,000 ohm resistances or his own modification without the resistances was used. Diagrammatic illustrations of the differences between the Wilson and Goldberger central

terminal connections are shown in fig. 9.

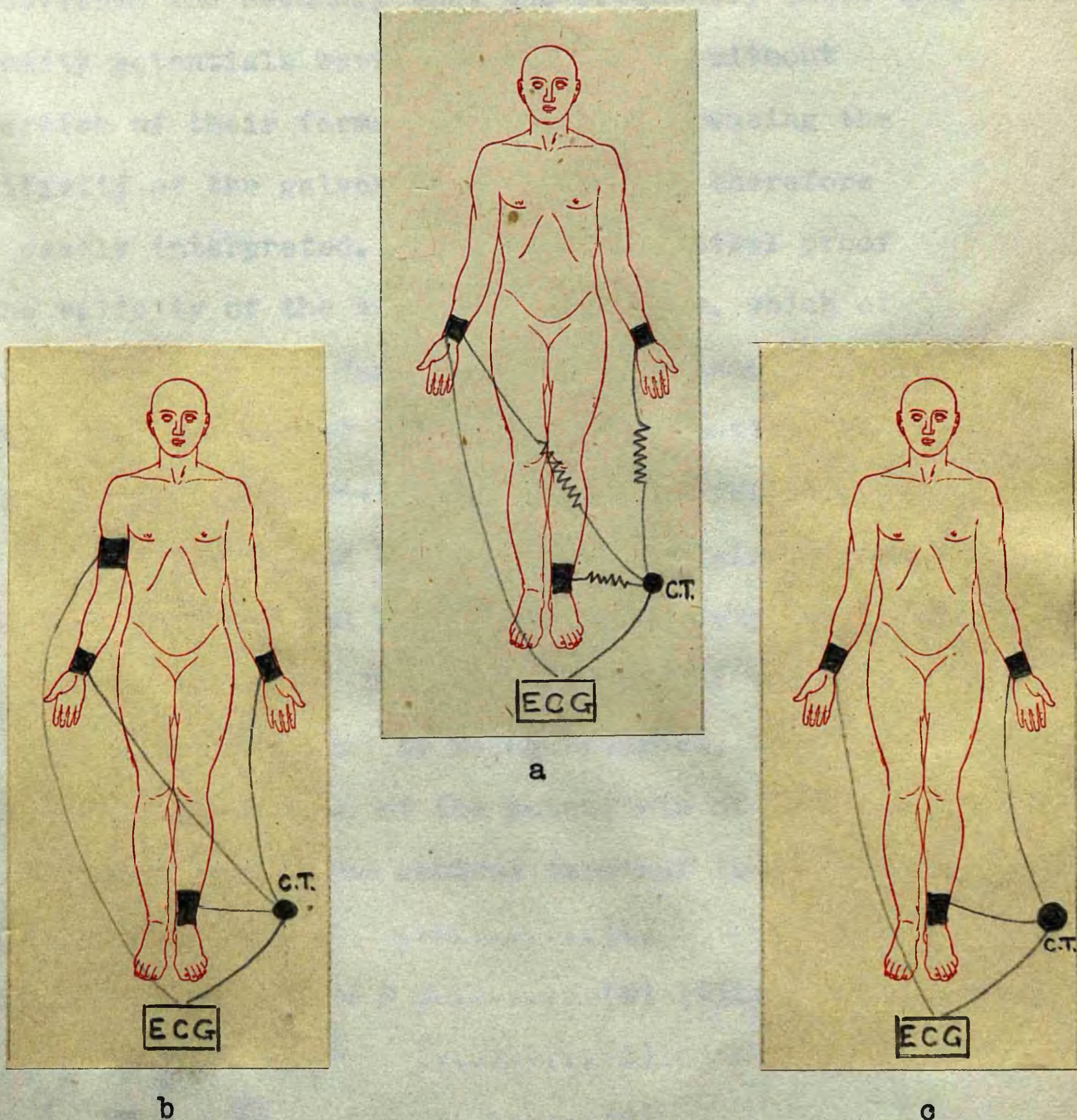


Fig. 9. Diagrammatic representation of the connections of the Wilson and Goldberger terminals for the right arm extremity potential.

a. Wilson terminal for unaugmented VR.
b. Goldberger terminal for unaugmented VR.
c. Goldberger terminal for augmented VR.

-ᴡᴡᴡ- represents 5000 ohm resistance.

The two main advantages of the augmented method were firstly that when the Goldberger terminal was employed the need for an additional exploring electrode on the limb was obviated and secondly that the frequently small unipolar extremity potentials were rendered larger without distortion of their forms and without increasing the sensitivity of the galvanometer, and were therefore more easily interpreted. Simple mathematical proof of the validity of the augmented technique, which of course depends on the demonstration by Wilson et al. (1931b) that the sum of the extremity potentials at any instant is zero, was given briefly as follows:-

If VR, VL and VF are the potentials of the right arm, left arm and left leg respectively, and if VT is the potential of the central terminal when the augmented right arm lead is being recorded, then VT is equal to the mean of the potentials of the two extremities to which the central terminal is connected.

i.e. $VT = \frac{VL + VF}{2}$ ....(1)

But, $VR + VL + VF = 0$ ....(2) (Wilson et al. 1931b)

$\therefore \frac{VL + VF}{2} = -\frac{VR}{2}$ ....(3)

$\therefore VT = -\frac{VR}{2}$ ....(4)

But, $aVR = VR - VT$ ....(5)

Where aVR is the augmented right arm potential.

$\therefore aVR = VR - (-\frac{VR}{2})$

$= \frac{3}{2} VR$ ....(6)

Similarly, $aVL = \frac{3}{2} VL$ ....(7)

and $aVF = \frac{3}{2} VF$ ....(8)

where aVL and aVF are the augmented left arm and left leg potentials respectively. The relationship between the augmented unipolar limb leads and the standard limb leads was worked out on similar lines (Goldberger, 1942b). It can be shown that

$$VR = -\frac{I + II}{3}$$

and $$VL = \frac{I - III}{3}$$

and $$VF = \frac{II + III}{3}$$ (Wilson et al. 1931b).

But $aVR = \frac{3}{2} VR$

and $aVL = \frac{3}{2} VL$

and $aVF = \frac{3}{2} VF$ (Goldberger, 1942a).

$$\therefore \quad aVR = -\frac{I + II}{2}$$

and $$aVL = \frac{I - III}{2}$$

and $$aVF = \frac{II + III}{2}$$.

In a further series of articles Goldberger (1944a,b, 1945b,c,d) and Goldberger and Schwartz (1945, 1946) utilised the modified technique in their approach to certain electrocardiographic problems, and stressed particularly the fundamental importance of the position of the heart on the production of the various unipolar patterns. Some indirect evidence in support of the Einthoven triangle hypothesis was also presented by Goldberger (1945 a). He asserted that if the theory were correct, the following corollary could also be accepted, "namely, that every two points on the surface of the body lying on the same plane as the source of electrical activity and separated by an angle of 180° have values equal in magnitude but opposite in polarity". The mean potential of two such points would of course be zero. In practice various points in the frontal plane were paired with the right arm until the two which yielded the greatest positive and negative values respectively of QRS were found. By joining these, an indifferent electrode was formed and this was used to record extremity leads which were then compared with augmented extremity leads obtained in the ordinary way. Allowing for the effect of augmentation, corresponding leads were found to be practically identical. It was admitted that the technique was relatively crude and in fact the experiments are not very convincing, particularly since some of the points used were much nearer the heart than others.

Such then was the background against which the work of this thesis was commenced in 1947. Even at that time, it seemed clear that unipolar electrocardiography rested on a sound mathematical and experimental basis and had already yielded valuable clinical information. Nevertheless, there existed a considerable body of opinion which was distrustful of the method and continued to rely on various empirical systems of leading. Furthermore, apart from the articles of Goldberger himself, there was no available information regarding the relative merits of the original unipolar technique and of the modifications which he had recently introduced. These considerations indicated that a comprehensive comparative study of the different methods was desirable. Several observations had been made on the relationship of the bipolar CR, CL and CF types of chest lead (Roth, 1935, Wood and Selzer, 1939, Wolferth and Wood, 1940), and a more recent analysis of the CF and V leads (Wallace and Grossman, 1946) had been interpreted in favour of the former. The only previous direct comparison of the CR, CL and CF and V chest leads and the unipolar extremity leads however, was that of Hecht (1942) who used the Wilson central terminal for recording the unipolar leads. From a study of twenty normal individuals, he concluded that in the CR, CL and CF chest leads considerable distortion was produced by the remote electrode and that this was absent or at least minimal when the central terminal method was employed. The present investigation includes a series of 60 cases, 30 normal and 30 abnormal, in whom standard leads, unipolar limb leads and multiple precordial leads of the V, CR, CL and CF types were obtained. Comparison of the Wilson and Goldberger methods of derivation of the unipolar chest leads and of the various forms of augmented and unaugmented extremity leads were also made in these and other cases. Some of the results were presented in a paper read before the British Cardiac Society in October, 1948, and subsequently published in abstract (Cameron, 1949), in which it was stated that the V leads represent the mean of the CR, CL and CF leads, i.e. that the distorting effect of the remote electrode is thereby reduced to a minimum. At that time, there was some diversity of opinion regarding the advantages and disadvantages of the V, CR and CF leads (Bain and Redfern, 1948, Evans, 1949, Leatham, 1949, Wood, 1949), and in a recent article Leatham (1950) has stated that in practice, while the CF leads are admittedly inferior, the V leads have no real superiority over the CR leads. The British Cardiac Society (1949) has, however, recommended the general adoption of the unipolar V leads and, in addition to the six points already mentioned from which multiple chest leads have usually been taken, has also defined points 7 and 8 at the same level as points 4 to 6 but in the posterior axillary line and below the apex of the scapula respectively, as additional possible sites. Leads from corresponding points on the right side of the chest are numbered in the same way and are distinguished by the suffix R, e.g. V3R.

Finally it may be mentioned that some former critics of the Wilson central terminal have now, as a result of a comparative study of the V, CR, CL and CF leads and of some elaborate immersion experiments, expressed the opinion that the unipolar leads are to be preferred to any of the bipolar leads (Dolgin et al, 1949a,b).

Though the unipolar technique has thus been widely accepted, the choice between the Wilson and Goldberger terminals remains at present a matter of individual preference. In the paper already quoted (Cameron, 1949) certain discrepancies between the extremity potentials recorded by the two methods were briefly mentioned and recently the retention of the 5,000 ohm resistances has been advocated on both practical and theoretical grounds (Bryant et al, 1949, Rappaport et al, 1949). Further observations relating to this question and based on a section of this thesis were presented in a communication to the British Cardiac Society in May, 1951 (Cameron, 1951).

SECTION 2.

General Description of Apparatus and Method.

Standard apparatus.

(a) Galvanometer.

All the electrocardiograms were recorded on a Cambridge table model of the string galvanometer with vertically falling camera.

The instrument was employed throughout at the usual sensitivity of 1 centimetre equal to 1 millivolt. A record of the standardisation was included in each tracing for subsequent verification. No tracing showing a difference of more than + or - 0.1 millivolt from the standard was accepted for analysis.

(b) Limb electrodes.

Ordinary Cambridge plate electrodes of the strap-on type were used for the standard and unipolar limb leads.

(c) Contact medium.

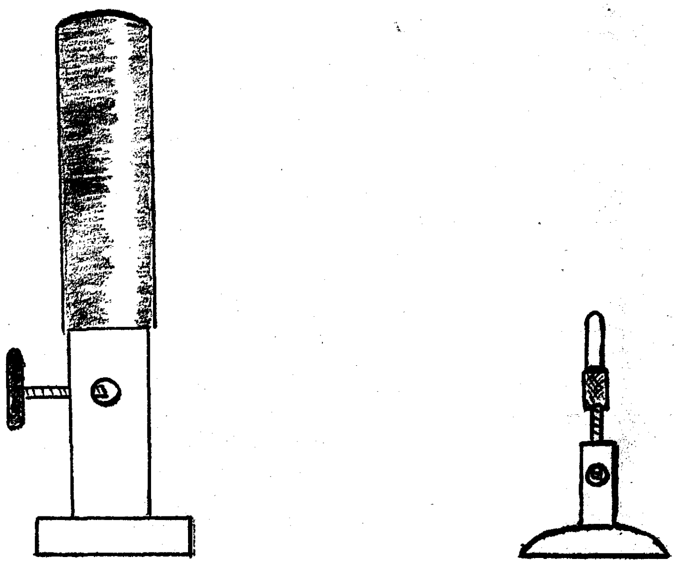
Cambridge electrode jelly was used for all skin-electrode connections. This was well rubbed into the skin, but care was taken to ensure that there was no excess of jelly and that the contact area, particularly in the case of the chest leads, was limited to the size of the electrode.

Special apparatus.

As a large number of leads had to be recorded from each patient, an effort was made to devise some suitable apparatus to shorten the time involved. This consisted mainly of (a) light weight chest electrodes, (b) a special chest electrode holder, and (c) a multiple switch box. To some extent, these three were interdependent and it may be explained that they were designed primarily for specific experimental and research purposes, and not for ordinary routine work.

(a) The chest electrodes.

Several trials with suction electrodes and with ordinary chest electrodes held in place by perforated rubber straps proved unsatisfactory, particularly for the work on posture and respiration. Ultimately, the best arrangement was found to be the use of light weight chest electrodes in conjunction with a large electrode belt. These electrodes were constructed from circular Cambridge chest electrodes of the manually applied type (fig. 10). The vulcanite handle was discarded, but the electrode head was left unchanged in diameter (2 cm.) and thickness, though it was tapered off round its edge. The rest of the electrode was reduced to the minimum weight by shortening the terminal post to 1 cm. in length, and machining it to a fraction (about one third) of its original thickness. A small hole for the metal pin of the lead wire was bored halfway down the terminal, which was also tapped for a small vertical retaining screw. Practically the whole weight of the electrode was therefore in the contact head. Electrodes of this type were found to be easily and closely applied to the chest wall by the special belt.



Original. Modified.

Fig. 10.

(b) The electrode holder.

A special electrode belt (fig. 11) was supplied to specification through the courtesy of Messrs Ioco Limited, Anniesland, Glasgow.

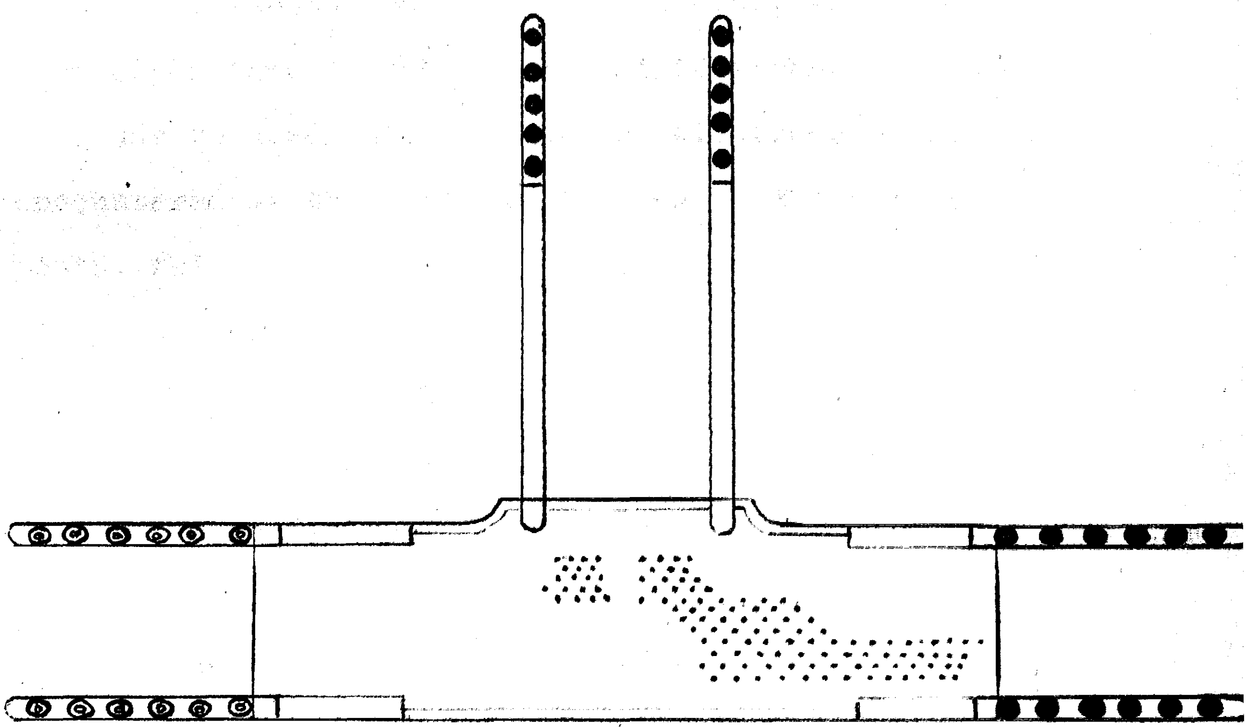


Fig. II

It was made of pure $\frac{1}{16}$ inch thickness rubber and was shaped to fit round the axillae. The total length was 28 inches, the centre piece being 12 inches and the side pieces 8 inches each. Straps were attached to fasten round the back and over the shoulders. To accommodate the posts of the electrodes, rows of $\frac{1}{16}$ inch diameter holes were punched as shown. The holes in each horizontal row were $\frac{1}{2}$ inch apart and the rows themselves were $\frac{1}{4}$ inch apart. This arrangement proved adequate to cover all the various electrode positions encountered in the subjects studied. The electrode posts, which were $\frac{3}{16}$ inch diameter, were readily inserted through the punch holes and were at the same time tightly gripped by the rubber. When fitted firmly round the chest wall, the total stretch of the belt was approximately 3 inches.

The procedure was, first to mark on the chest the positions 1 to 6. The vertical distance between 2 and 4 was then measured and suitable horizontal rows for the electrodes were easily chosen. The horizontal distances between 2 and 4 and between 4 and 6 were then measured and an allowance of usually $\frac{1}{2}$ inch for stretch was made in each case. The belt positions for electrodes 1, 2, 4 and 6 were then found. Electrode 3 was placed midway between 2 and 4, and electrode 5 was approximately midway between 4 and 6.

A test application of the belt was made and it could be verified that the imprint of the electrode coincided with the marked position on the chest. After a small amount of jelly had been applied to each electrode the belt was then fastened in place and each electrode was rotated for a short time to ensure good contact.

As a further precaution to prevent spread of jelly and also to aid in the application of the electrode to the chest wall, a small rubber washer slightly larger than the electrode itself was fitted over the electrode and under the belt (fig. 12).

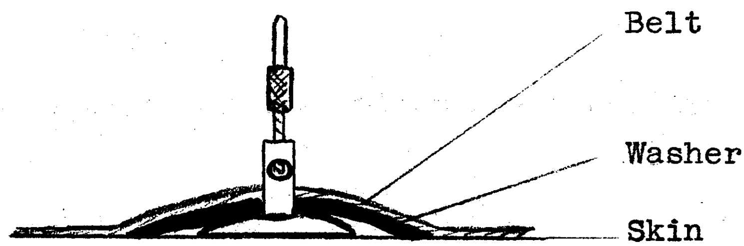


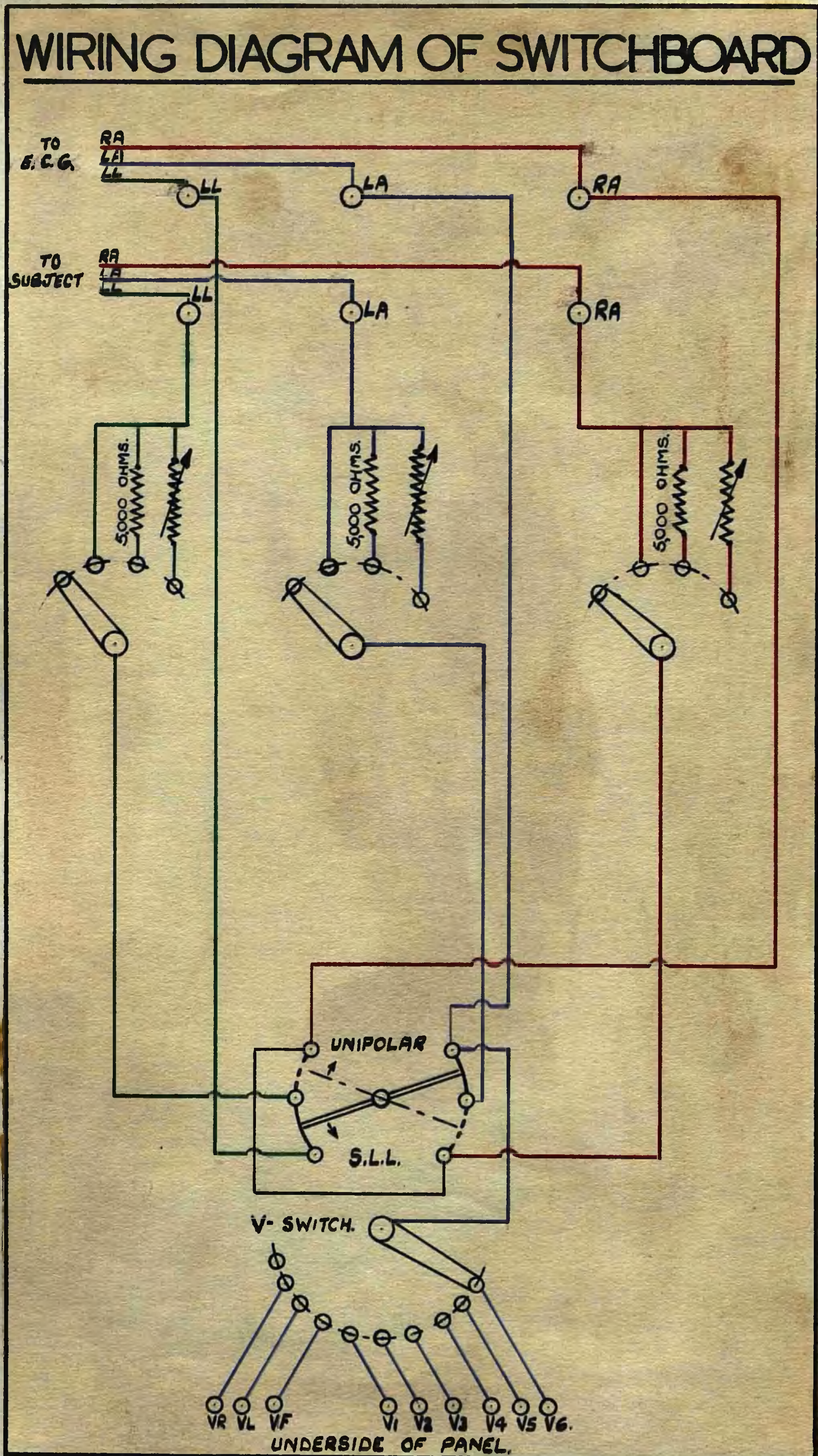
Fig. 12.

On removal of the belt at the end of each investigation the accuracy of the application could again be checked for the imprint of the electrode was clearly seen for some time on the skin. Furthermore, since the belt was skin tight, the jelly remained moist under the electrode for an indefinite period, and no trouble was encountered even in prolonged experiments. In no case did jelly tend to spread beyond the rubber washer.

(c) The switching device.

This was designed to facilitate (1) the recording of multiple chest leads and unipolar extremity leads of different types and (2) the investigation of the effects of varying resistances in the limbs of the central terminal. The wiring system is shown in fig. 13 and a simple line drawing of the switch box itself in fig. 14.

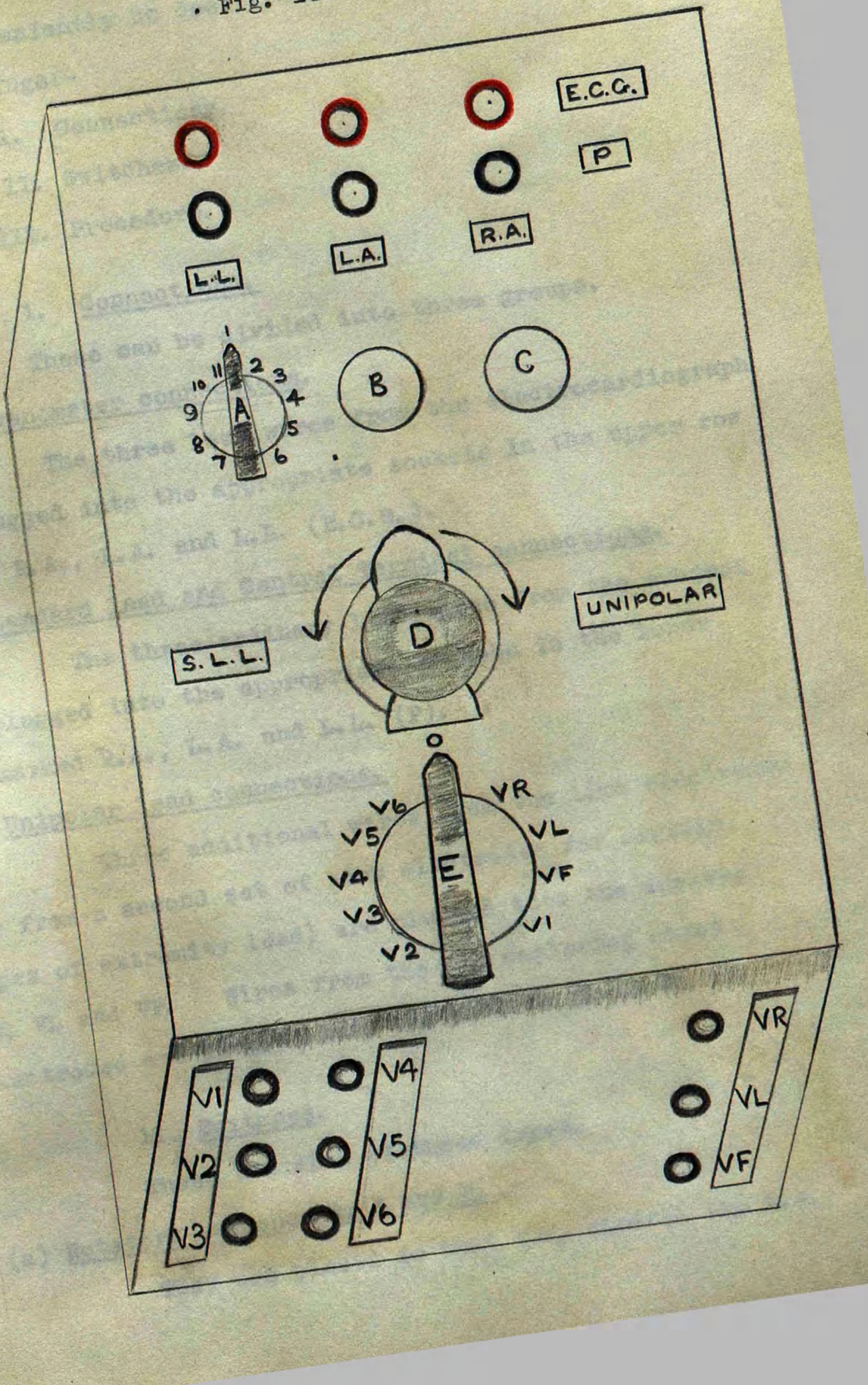
This switch box was designed and constructed personally.



WIRING DIAGRAM OF SWITCHBOARD
TO E.C.G.
RA
LA
LL
LL
LA
RA
TO SUBJECT
RA
LA
LL
LL
LA
RA
5,000 OHMS.
5,000 OHMS.
5000 OHMS.
UNIPOLAR
S.L.L.
V- SWITCH.
VR
VL
VF
V1
V2
V3
V4
V5
V6.
UNDERSIDE OF PANEL.

Fig. I3

. Fig. 14.


E.C.G.
P
L.L.
L.A.
R.A.
A
1 2 3 4 5 6 7 8 9 10 11
B
C
D
UNIPOLAR
S.L.L.
E
0
VR
VL
VF
V1
V2
V3
V4
V5
V6
VR
VL
VF
V1
V2
V3
V4
V5
V6

It may conveniently be described under the following three headings:-

1. Connections.

11. Switches.

111. Procedure.

1. <u>Connections.</u>

These can be divided into three groups.

(a) <u>Galvanometer connections.</u>

The three lead wires from the electrocardiograph are plugged into the appropriate sockets in the upper row marked R.A., L.A. and L.L. (E.C.G.).

(b) <u>Standard lead and Central Terminal connections.</u>

The three ordinary limb wires from the subject are plugged into the appropriate sockets in the lower row marked R.A., L.A. and L.L. (P).

(c) <u>Unipolar lead connections.</u>

Three additional wires from the limb electrodes (or from a second set of limb electrodes for certain types of extremity lead) are plugged into the sockets VR, VL and VF. Wires from the six exploring chest electrodes are plugged into the sockets V1 to V6.

11. <u>Switches.</u>

These are also of three types.

(a) <u>Rotatory switches A, B and C.</u>

They are placed so that they control the R.A., L.A. and L.L. ordinary limb wires respectively. They can move through the following range individually or synchronously:-

(1) Break.
(2) No resistance.
(3) 5,000 ohms.
(4) 10,000 ohms.
(5) 20,000 ohms.
(6) 50,000 ohms.
(7) 100,000 ohms.
(8) 200,000 ohms.
(9) 500,000 ohms.
(10) 1 megohm.
(11) 5 megohms.

(b) Central switch D.

This is a double-pole, change-over switch and has only two positions:-

(1) SLL, for recording the three standard limb leads
(2) Unipolar, for recording all other leads.

In position (1), the ordinary limb lead wires from the subject go straight through to the corresponding lead wires of the electrocardiograph.

In position (2), the lead wires from the subject are united to form a central terminal, which is automatically connected to the R.A. wire of the electrocardiograph.

By the same movement, the L.A. wire of the electrocardiograph is connected to the unipolar selector switch (E), while the L.L. wire is broken. All leads in this position are therefore recorded through Lead 1 of the electrocardiograph with correct polarity.

(c) Unipolar lead selector switch.

This is a simple rotatory switch with ten consecutive positions as follows:-

0: Zero or "off" position.
1: VR.
2: VL.
3: VF.
4: V1.
5: V2.
6: V3.
7: V4.
8: V5.
9: V6.

111. Procedure.

(a) To record the three standard limb leads.

(1) The three limb switches are set at no resistance.

(2) The central switch is set at S.L.L.

(3) The unipolar selector switch is set in the zero position.

The three standard leads are then recorded through the selector switch of the electrocardiograph as usual.

(b) To record all other leads.

(1) The electrocardiograph is set for Lead 1.

(2) The central switch is moved to unipolar.

The subsequent procedure depends on the type of lead to be recorded.

A. Unipolar extremity leads.

(1) The appropriate site of the lead (VR, VL or VF) is selected on the unipolar selector switch.

(2) The type of lead is controlled by the three limb switches.

(a) Unaugmented Goldberger: all three switches are set at no resistance.
(b) Unaugmented Wilson: all three switches are set at 5,000 ohms.
(c) Augmented Goldberger: the switch on the limb concerned is at break. The other two are at no resistance.
(d) Augmented Wilson: the switch on the limb concerned is at break. The other two are at 5,000 ohms.
(e) For further experimental purposes, resistances of varying magnitude can be introduced into any combination of limbs of the central terminal.

B. Chest Leads.

(1) The appropriate site of the lead (V1 to V6) is selected on the unipolar selector switch.

(2) The type of lead is controlled again by the three limb switches.

(a) Goldberger central terminal: all three switches are at no resistance.
(b) Wilson central terminal: all three switches are at 5,000 ohms.
(c) CR leads.
The L.A. and L.L. switches are broken.

The R.A. switch remains at no resistance.

(d) <u>CL leads</u>.

The R.A. and L.L. switches are broken.
The L.A. switch remains at no resistance.

(e) <u>CF leads</u>.

The R.A. and L.A. switches are broken.
The L.L. switch remains at no resistance.

(f) For further experimental purposes, resistances of varying magnitude can be introduced into any combination of limbs of the central terminal.

Nomenclature of leads.

In general the nomenclature recommended by the British Cardiac Society (1949) is used throughout this thesis. Thus the three standard leads are named in the usual manner. The unipolar limb leads are designated VR, VL and VF when they were taken by the unaugmented method and aVR, aVL and aVF when they were augmented. The unipolar chest leads are indicated by the letter V with the appropriate number added. Where these letters are used alone they refer to leads taken with the Goldberger terminal. All leads taken by the Wilson method with the 5,000 ohm resistances in the central terminal are distinguished by the postscript (W). Where distinction between the Goldberger and Wilson leads is necessary, this is indicated by the postscripts (G) and (W) respectively. The bipolar chest leads are named CR, CL and CF as is customary.

In most of the cases the chest leads were recorded from positions 1 to 6 as standardised by the British Cardiac Society (1949), but in some cases leads were also taken from positions 7 and 8 on the left side of the chest, and from corresponding positions 3R to 8R on the right side of the chest, and from position 9 in the vertebral line on the same level as positions 4 to 8.

Nomenclature and measurement of deflections.

The recommendations of the American Heart Association (1943a) for the naming and measurement of the ventricular deflections have been adopted. Thus Q is an initial negative deflection, R is the initial or first positive deflection, S is the first subsequent negative deflection; R', S', etc. are subsequent positive and negative deflections if present. The term QS is applied to a monophasic negative deflection. QS, Q and S are considered separately for statistical purposes. Where necessary the QRS complex is described as "notched", "slurred" or "vibratory".

In some of the descriptive sections, small and capital letters are used to indicate the relative sizes of the deflections in various unipolar patterns, e.g. qRs, qR, RS, etc.

For purposes of measurement the isoelectric level is taken as the level of the trace at the beginning of the P wave. The reference level for all QRS waves and for displacement of the RS-T junction is the level of the trace at the beginning of the QRS complex. For the RS-T segment, T wave and U wave, the reference level is the isoelectric line where this can be determined; otherwise it is the same as for the QRS complex. Diphasic waves are described as $\pm$ or $\mp$ depending on whether the positive or negative phase comes first.

SECTION 3.

Preliminary investigations.

(a) Prolonged application of electrodes and continuous use of the electrocardiograph.

As most of the subsequent experiments necessarily extended over a period of one to two and a half hours, it was considered essential to eliminate any possible effect on the electrocardiogram of such prolonged application of the electrodes and continuous use of the machine. Results of some of these tests on the three standard leads are shown in Plate 1. The first set of tracings A,B,C,D, were taken at half-hourly intervals from a normal subject. Between each recording, the machine was switched off and left unused. The corresponding leads are all identical in form and amplitude. It can therefore be concluded that limb electrodes applied carefully in the usual manner with electrode jelly will continue to provide even contact for at least two hours.

The other two sets of tracings A,B are the standard leads from two individuals at the start and finish respectively of investigations lasting in each case for two and a half hours. During this period the machine was in continuous action. The upper set was from a normal subject and the lower from a patient with auricular fibrillation. Again it can be seen that corresponding tracings are identical. Continuous use of the machine therefore is not associated with any alteration in its recording properties.

Similar results were obtained with the unipolar limb leads and with the precordial leads using the special belt and electrodes, (Plates 2a and 2b).

(b) The effect of meals on the electrocardiogram.

Changes in the electrocardiogram after eating were first noted by Waller (1913c) who found that after a meal the electrical axis tended to become more horizontal. He attributed this to distension of the stomach which caused the heart to become more transverse. Similar alterations had been observed earlier (Hoffmann, 1909) when the stomach was distended by gas, and were also thought to be due to counter-clockwise rotation of the heart around its antero-posterior axis. No further attention seems to have been paid to this matter until Gardberg and Olsen (1939) carried out a series of observations in several healthy individuals before and after an ordinary mixed meal. They found in most cases a notable decrease in the height of the T wave in all three standard leads, and particularly in lead 111, after eating. There was however no equivalent change in the direction of the electrical axis. A more detailed study was made by Simonson et al, (1946), who in general confirmed these results and also noted some variable changes in a few cases in certain of the CF leads. More recently Goldberger (1949d) has shown that administration of oral glucose can cause a decrease in height of the T waves in the unipolar precordial leads and has suggested that this is due to a lowered serum potassium associated with hepatic glycogenesis.

Whatever the actual causation of the changes, it was considered desirable from the point of view of the present comparative investigations to obtain some idea of their magnitude, and more especially of their possible duration. The three standard leads, the unipolar limb leads and precordial leads V1 to V6 were recorded in one normal individual immediately before and at half-hourly intervals up to two hours after the taking of an ordinary mixed meal. The complete set of tracings is shown in Plates 3a and 3b. Column A is the control series and columns B, C, D, E are the subsequent half-hourly recordings. The main change is slight decrease in amplitude of the T waves in leads 11, 111, aVR and aVF immediately after eating, with gradual return to normal after two hours. Similar but much more obvious changes occur in the T waves in all the precordial leads, especially leads V2, V3, V4 and V5. The T wave in lead V4, for example, shows a reduction from 12 to 7 millivolts. In all leads there is a gradual return to normal at the end of two hours. There are no noteworthy variations in the P wave or QRS complexes.

Significant changes may therefore be produced in the electrocardiogram, particularly in the precordial leads, immediately after eating, with subsequent return to normal after two hours. For this reason none of the comparative investigations were commenced until at least two hours after the previous meal.

(c) <u>The effect of local cooling of the heart on the electrocardiogram.</u>

Transitory decrease in height of the T waves in leads 11 and 111 in normal subjects immediately after drinking 600 c.c. of iced water was observed by Wilson and Finch (1923). The effect was attributed to cooling of the postero-inferior aspect of the apex of the left ventricle, and not to any mechanical displacement of the heart, as an equal volume of warm water produced no such change. According to Robinson et al. (1939) the same experiment with cold water caused a decrease of R in lead 1VF, but no alteration in the T wave.

To test the possible effect of fluid intake on the unipolar leads investigations were carried out on two normal subjects. In the first case (Plate 4), a control series of tracings (A) was made. One pint of iced water at a temperature of 35°F. was then drunk as quickly as possible and another set of tracings (B) was recorded immediately thereafter. About half an hour later the subject drank one pint of tepid water and a further series (C) was then taken. The only noteworthy change after drinking the cold water was a decrease in the T waves in leads 11 and 111. There was no very significant alteration in the unipolar extremity or chest leads, though the T wave in lead V1 from being slightly negative became flat, and the T wave in lead V2 showed a slight increase in amplitude. No changes were noted in the P waves or QRS complexes. All the tracings after drinking warm water were indistinguishable from the control series.

In the second case (Plate 5) a control series (A) was taken. One pint of cold tap water at a temperature of 45°F. was then drunk quickly and another series (B) was recorded immediately, followed directly by a third series (C). The whole process occupied approximately 25 minutes. No obvious changes occurred in any of the leads in series (B). In series (C) however there was slight decrease in the T waves in lead 111 and lead aVF and again slight increase in the T wave in lead V2 (from 6 to 8 millivolts).

Conclusion.

While transitory changes of note may occur in the T waves in the limb leads after drinking ice-cold water, these are minimal when ordinary cold tap water is taken. No significant changes occur in either case in the unipolar extremity or precordial leads. It would perhaps be interesting to relate the slight increase in the T waves in lead V2 to the giant T waves sometimes found in the chest leads after posterior myocardial infarction, but such inferences are not justifiable from the results of the present experiments.

SECTION 4.

The augmented and unaugmented unipolar extremity potentials.

Theoretically the extremity potentials can be recorded by four different methods. Thus using a central terminal of the original Wilson type with 5,000 ohm resistances in each of its branches, the ordinary or unaugmented potential may be obtained ("W"). By breaking the connection of the central terminal to the extremity concerned the augmented potential can be recorded ("aW"). Similarly if a terminal of the Golderberger type without resistances is employed, again the ordinary or unaugmented ("G") and the augmented ("aG") potentials can be recorded. The two unaugmented potentials should be identical and so also should the two augmented potentials; in addition the latter should be half as great again as the former.

The object of the experiments now described was to determine whether these theoretical relationships were borne out in actual practice.

Method.

With the usual three limb electrodes placed at the wrists and left ankle, it is possible to record only three of the above types of lead, namely W, aW and aG. The W type is recorded by using the one electrode for both the exploring and central terminal connections. The G type cannot be recorded by this method because such an arrangement results in no deflection on the galvanometer. An additional exploring electrode must therefore be placed on the limb to record this lead.

To compare all four types of lead as directly as possible therefore, the central terminal in each case was formed by connections from distal electrodes in the usual positions just above the wrists and the left ankle, while additional exploring electrodes were placed proximally just above the elbows and left knee respectively. With this arrangement the following seven types of extremity potentials were recorded (see fig. 15).

<u>A: distal electrodes only.</u>

1: W

2: aW

3: aG

<u>B: additional proximal exploring electrodes.</u>

4: W

5: aW

6: G

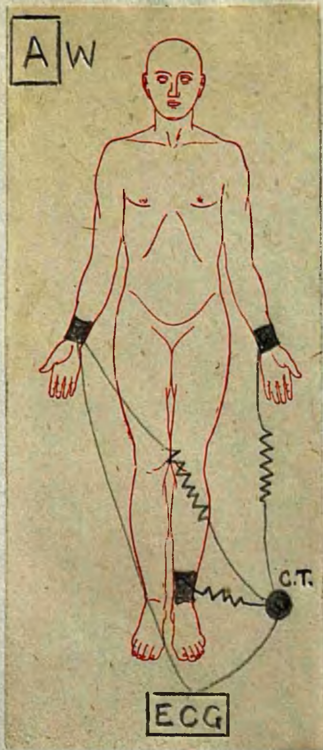
7: aG

The three extremity potentials were recorded by each of these methods in a total of eight cases, four normal and four with heart disease of various types. Two sets of standard leads were also recorded, one from the distal and one from the proximal electrodes.

Figure I5

Diagrams illustrating the seven types of lead described in text. In each case the connections shown are for recording the right arm extremity potential.

 represents 5000 ohm resistance.



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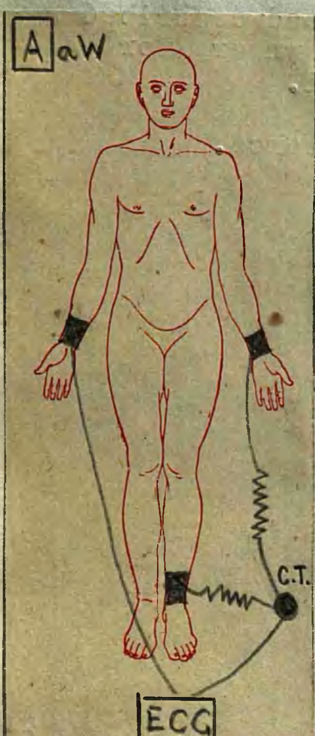

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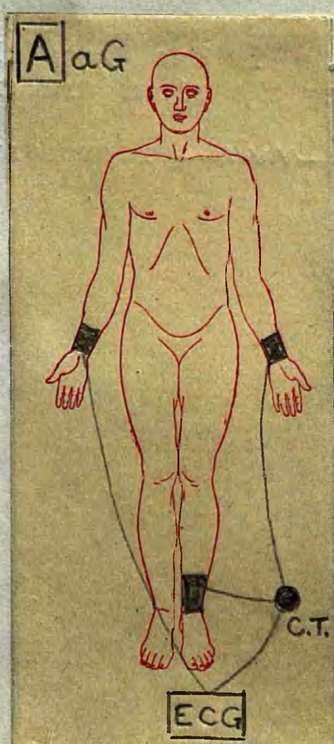

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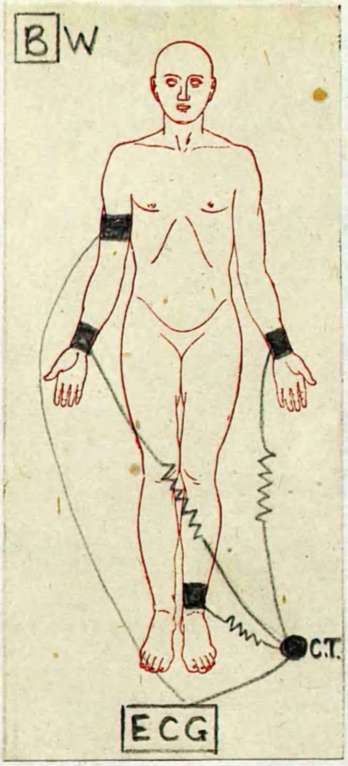

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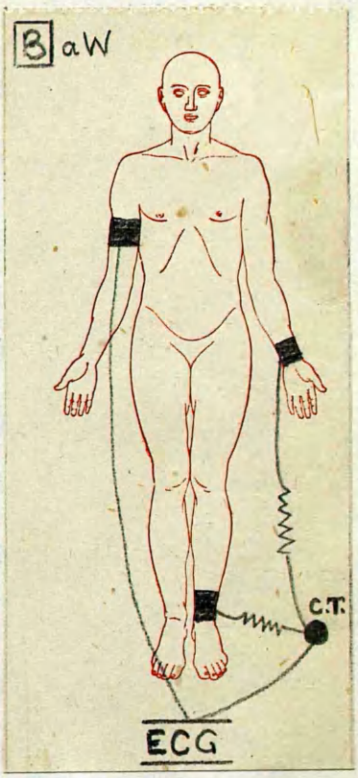

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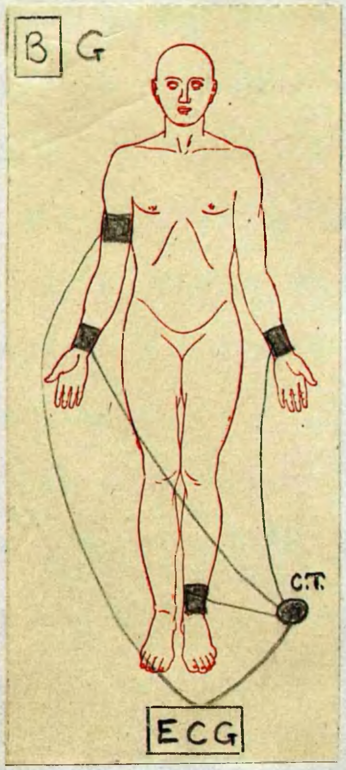

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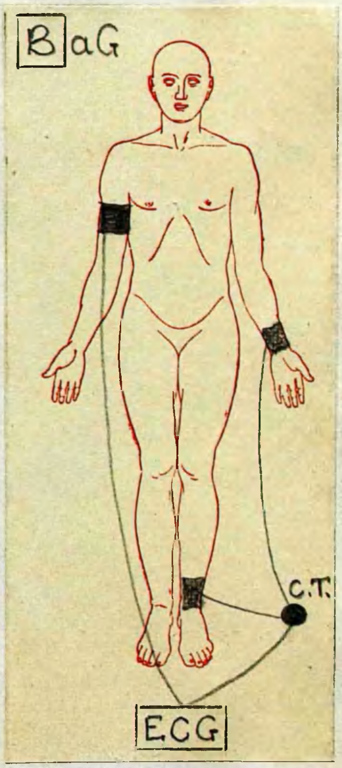


7

Results.

The complete sets of tracings from these cases are shown in plates 6 to 13 with their accompanying descriptions.

The two sets of standard leads in each case are identical with the exception of minor differences in lead 111 in cases 2 and 7 due to respiratory variation. This is in agreement with the traditional idea of regarding the limbs as mere linear extensions of their attachments to the trunk.

Noteworthy differences are present between the various types of unipolar extremity leads in every case. While these differences are readily visible in most instances, it was considered advisable for more accurate comparison to measure the deflections in the various leads. Measurements were made to the nearest 0.2 mm. In obtaining the value for the QRS complex the algebraic sum of the constituent deflections was determined. The values of the unaugmented leads were multiplied by 3/2 to make them comparable to the augmented leads. Measurements of the standard leads were also made and by use of the appropriate formulae the theoretical values for the augmented extremity potentials were calculated. These theoretical values were then used to assess the accuracy of the observed values obtained by the W, aW and aG methods. This was considered justifiable since with correct standardisation, bipolar leads are not affected by ordinary variations in skin resistance. The individual measurements for each case are shown in tables 1 to 8. The theoretical value is given first in red type.

The results are analysed in two ways, (a) the observed values of the different types of lead are compared with each other and (b) the observed values are compared with the theoretical value.

(a): The W leads from the distal electrodes are in every case significantly smaller in amplitude than the corresponding W leads from the proximal electrodes.

The aW leads from the distal electrodes are identical in every case with the corresponding aW leads from the proximal electrodes.

The aW leads from the proximal and distal electrodes and the W leads from the proximal electrodes satisfy the theoretical relationship which should exist between them i.e. aW = 3/2 W.

The aG leads from the distal electrodes frequently show considerable differences in amplitude from the corresponding aG leads from the proximal electrodes. Sometimes the one and sometimes the other is the greater.

The relationship of the aG leads to the G lead is variable and the theoretical equation is seldom satisfied.

Differences between the aW leads and the aG leads are evident in almost every case. On the whole the deflections in the aG leads tend to be larger than those in the corresponding aW leads. Obvious differences in configuration may occur as in case 6 where VL in all the W and aW leads has an rs pattern whereas in the G and aG leads it has a QS pattern.

(b): The observed values in the W leads from the distal electrodes are in every case significantly smaller than the theoretical values.

The observed values in the two aW leads and in the W leads from the proximal electrodes are constantly close to the theoretical values.

The observed values in the two aG leads and in the G leads are in most cases significantly different from the theoretical values.

It is clear in some cases that the aG leads tend unduly to resemble one of the standard leads, either upright or inverted. Thus in VR the aG lead may resemble an inverted lead 1 or an inverted lead 11; in VL it may resemble an upright lead 1 or an inverted lead 111; in VF it may resemble an upright lead 11 or an upright lead 111. This possibility is considered further in sections 5 and 7.

Conclusions.

The original Wilson method of recording the unaugmented extremity potential using a common electrode for the central terminal and exploring connections is unsatisfactory, as it usually registers only a fraction of the actual potential.

Ordinary and augmented potentials recorded with a Goldberger terminal frequently fail to satisfy the theoretical relationship which should obtain between them. They also differ significantly in many cases from the theoretical values calculated from the standard leads.

The most consistent results are achieved by using the Wilson terminal with an additional exploring electrode for the ordinary extremity potential, or by adopting the Goldberger principle of augmentation and retaining the resistances of 5,000 ohms in the branches of the terminal.

SECTION 5.

Further Comparison of the W, aW and aG Extremity Potentials.

Since in practice it is inconvenient to employ an extra electrode to record the extremity potential it was decided to investigate in a larger group of cases the three types of lead which can be obtained from the customary three electrodes.

Method.

A series of forty cases was studied of which twenty-six were normal and fourteen abnormal. The three standard leads were recorded first. Each extremity potential was then taken by the three different methods, W, aW and aG as described in section 4.

Results.

Tracings from seven representative cases are shown in plates 14 to 20, with their accompanying descriptions. The other cases are included amongst those illustrated in plates 29 to 88.

The measurements of the extremity potentials and the calculation of their theoretical value from the standard leads were made in the manner already described in section 4. The detailed results for each case are shown in tables 9 to 48. The theoretical value is again given first in red type.

The values of the W leads have been multiplied by 3/2 to make them directly comparable with the aW and aG leads.

The results are analysed in two ways, (a) the observed values of the three types of lead are compared with each other and (b) the observed values are compared with the theoretical value obtained by calculation from the standard leads.

(a). In practically every case the value of 3/2 W is significantly smaller than the value of aW.

In eight cases there are no significant differences between the aW and aG leads. In the remaining thirty-two cases the differences are significant. In some cases all three extremity potentials are affected; in others only two are affected. Of the three potentials aVL shows the greatest and most frequent differences.

(b). The value of 3/2 W is in most cases significantly smaller than the theoretical aV value.

The value of aG differs significantly from the theoretical aV value in thirty cases. In most instances the aG value is greater than the theoretical. All three extremity potentials may show differences but often only two of them are affected. Lead aVL tends to show the error most clearly. It is possible in many instances to show that the error in the aG lead is due to its resemblance to one of the standard leads either upright or inverted, and that this in turn depends upon a disparity of the resistances in the branches of the central terminal (e.g. cases 1 to Vll). These findings apply both to the normal and abnormal cases.

Over the whole series the value of aW corresponds closely to the theoretical aV value. In the few cases where there is a significant difference between the aW and theoretical aV values, the corresponding aG value is usually more erroneous still. Occasionally in cases of this type where the aW value is greater than the theoretical aV value it is found that 3/2 W is closer to the theoretical value. This is due to a combination of two errors. The first error affects only 3/2 W and reduces its value; the second error affects both 3/2 W and aW and increases their values. The final result therefore is that aW is greater than the theoretical aV value while 3/2 W is approximately equal to it. The converse of this is seen in a few cases where aW is significantly smaller than the theoretical aV value, for in these cases 3/2 W is smaller still.

It may be noted that the method of obtaining the QRS value by algebraic summation of its component deflections sometimes tends to lessen the actual differences between aW and aG. For example in an RS type of complex both the R wave and the S wave in aG may be larger than the corresponding waves in aW. When these are added however the resulting values in the two types of lead may show little difference.

Statistical Analysis.

Statistical tests were applied to the values of the QRS and T waves to assess the accuracy of the three methods W, aW and aG. In each case the deviations (d) of the observed from the theoretical values were found by subtracting the numerical values of 3/2 W, aW and aG from the theoretical value obtained from the standard leads. The mean value of d for the forty cases ($\bar{d}$) and s, the standard error of $\bar{d}$, were found. The value of $t = \bar{d}/s$ was then used to test whether the mean deviations were significantly different from zero. The results are shown in table A.

For 3/2 W, the values of both QRS and T waves are significantly different from zero at the one per cent level in all three leads. The values are all positive indicating that the values of the waves obtained by this method are numerically smaller than the theoretical values.

For aG, the values of both QRS and T waves

TABLE A

Values of $\bar{d}$ and $t = \bar{d}/s$ for QRS and T for the three methods W, aW and aG in the three leads VR, VL and VF in the group of forty individuals.

LEAD	WAVE \ METHOD	3/2W $\bar{d}$	3/2W t	aW $\bar{d}$	aW t	aG $\bar{d}$	aG t
aVR	QRS	16.65	9.50**	1.075	1.50	-3.82	-1.80
	T	6.20	8.80**	0.25	0.94	-1.45	-2.10*
aVL	QRS	5.25	3.60**	1.30	1.63	-7.75	-2.93**
	T	2.17	5.84**	-.36	-1.60	-2.10	-2.75**
aVF	QRS	17.60	8.25**	1.07	1.60	-3.36	-2.17*
	T	6.50	10.70**	0.67	3.12**	-0.82	-2.12*

* Significant at 5% level
** Significant at 1% level

are significantly different from zero at the one per cent level in lead aVL and at the five per cent level in lead aVF. The value of the T wave in lead aVR is significantly different from zero at the five per cent level but the value of the QRS wave is not significantly different from zero. The values are all negative indicating that the values of the waves obtained by this method tend to be numerically larger than the theoretical values.

For aW, none of the values is significantly different from zero except that of the T wave in lead aVF which is significant at the one per cent level.

It can be concluded therefore that aW is by far the most accurate of the three methods. Of the other two methods W is most consistently inaccurate and aG is also inaccurate particularly with respect to lead aVL and to a lesser extent with respect to leads aVF and aVR.

The fact that the error in the aG method is greatest in lead aVL and least in lead aVR suggests that it may be at least partly due to current flow from points of high potential to points of low potential through the central terminal. Since the right arm is usually at a negative potential with respect to the central terminal while the left arm and leg, particularly the latter, are at a positive potential, such a flow is most likely to occur when the right arm and left leg are connected i.e. when lead aVL is being recorded, less likely to occur when the left arm and right arm are connected i.e. when lead aVF is being recorded, and least likely to occur when the left arm and left leg are connected i.e. when lead aVR is being recorded.

It should also be stated that the spread of the deviations in aW is significantly small compared with those in W and aG. Since the theoretical values of the extremity potentials calculated from the standard leads necessarily satisfy the equation $aVR + aVL + aVF = 0$, it can be concluded that in aW also the value of $aVR + aVL + aVF$ does not differ significantly from zero.

Conclusions.

Considerable differences are found in many cases between the three types of lead.

The W lead almost invariably records only a fraction of the actual extremity potential and is therefore unsatisfactory.

The aG lead frequently shows a significant error. The explanation lies partly in its tendency to be converted to a bipolar lead due to current flow through the galvanometer between the exploring electrode and one of the limbs of the central terminal and partly perhaps to current flow between the two limbs of the central terminal itself. These effects are due to inequalities of resistance in the branches of the central terminal, particularly if one or more of the resistances is low.

The most consistent results are obtained with the aV lead. In practice the retention of the 5,000 ohm resistances in the branches of the central terminal eliminates the distorting effect of any inequalities in resistance which are likely to be encountered. On both theoretical and practical grounds therefore it is the method of choice for recording the extremity potentials with the string galvanometer.

These conclusions are supported by the results of a statistical analysis of the data.

SECTION 6.

Comparison of the Wilson and Goldberger Methods of Recording the Unipolar Precordial Leads.

The object of the experiments described in this section was to determine whether there were any differences in the precordial leads recorded by the Wilson and Goldberger technique.

Method.

Seven cases were studied of which two were normal and five were abnormal. In each case the unipolar precordial leads were taken first with the Goldberger and then with the Wilson central terminal from positions 1 to 6. In one of the abnormal cases tracings were also taken from position 7.

Results.

The complete series of tracings from the seven cases are shown in plates 21 to 23, with their accompanying descriptions.

In every case except one differences of varying degree were found between the two types of lead. In two cases (A and F) the P wave, QRS complex and T wave were all affected; in three cases (B, D and E) the QRS complex and T wave were affected; in one case (G) only the T wave was affected. The differences were mainly in the amplitudes of the various waves and in each case they remained constant through all the precordial positions. Differences in configuration were also found in some cases. Thus in case A the P wave was uniformly upright in the V(W) leads but was diphasic, negative or flat in the V(G) leads; in cases D and E differences in configuration of the QRS complex occur in the transitional zone; in case F the T wave in position 6 is negative in V(G) and diphasic in V(W); in case G the T wave in position 3 is upright in V(G) and inverted in V(W).

Conclusion.

The frequency of the differences between the two types of lead in this unselected group of seven cases is significant and indicates that the choice of central terminal is of practical importance. The differences are variable and unpredictable and are presumably due to unequal skin-electrode resistances in the three branches of the central terminal. Such inequalities are minimised by the retention of the 5,000 ohm resistances in the central terminal.

SECTION 7.

The effect of external resistances on the unipolar leads.

As it was suspected that the differences between the Goldberger and Wilson unipolar leads were mainly due to inequalities in skin-electrode resistance, it was decided to study the effects on the unipolar limb and chest leads of introducing external resistances into the branches of the central terminal.

Method.

The switch-box was used as previously described to introduce resistances of varying magnitude into any desired combination of the limb connections. Two subjects were studied in detail, one with particular reference to the standard and unipolar limb leads, and the other with reference to the chest leads.

CASE 1.

(a) Standard limb leads.

The three standard leads were recorded in the usual manner. Equal resistances of 5,000 ohms were then introduced into each of the limb wires and the three leads were again recorded. The process was repeated with resistances of 10,000 ohms and 20,000 ohms respectively. Since the two limb wires for any standard lead are in series this procedure had the effect of increasing the total resistance in the lead circuit by 10,000, 20,000 and 40,000 ohms respectively. The galvanometer string had of course to be slackened appreciably at each stage to obtain the correct standardisation. By the time the fourth stage was reached it was obvious that it was becoming too slack for accuracy, so no further resistances were added.

(b) Unaugmented unipolar limb leads.

Unaugmented extremity potentials were recorded using a central terminal of the Wilson type with 5,000 ohm resistances in each of its branches. Serial tracings were then taken of the same leads with equal resistances of 10,000, 20,000 and 50,000 ohms respectively in the central terminal branches. Since the branches of the central terminal are connected in parallel the equivalent resistances in the galvanometer circuit were approximately 1,600, 3,300, 6,600 and 16,600 ohms respectively. The wire to the exploring electrode was left at no resistance throughout. Again the string required to be slackened a little at each stage but not nearly so much as with the standard leads. At the fourth stage however the string became too slack for accurate recording.

(c) Augmented unipolar limb leads.

The aVR lead was recorded by the Goldberger method with no resistances in either of the two branches of the central terminal. Equal resistances of 5,000 ohms were then introduced into the central terminal and aVR was again taken. The same process was repeated with equal resistances of 10,000, 20,000, 50,000, 100,000 and 200,000 ohms. The equivalent resistances thus placed in the galvanometer circuit were 2,500, 5,000, 10,000, 25,000, 50,000 and 100,000 ohms respectively. Again slight slackening of the string was required in the earlier stages and by the fourth stage accuracy was being lost.

The left arm wire of the central terminal was now put at no resistance and the left leg wire was put at 5,000 ohms. A tracing of aVR was then recorded. With the left arm wire remaining at no resistance the whole series of increasing resistances (10,000, 20,000, etc. up to 5 megohms) was thrown successively into the left leg wire and tracings were recorded at each stage. The process was then reversed, the left leg wire being fixed at no resistance and the serial resistances being added to the left arm. No compensatory slackening of the string was required in either of these experiments after the first stage.

Identical experiments were carried out with respect to leads aVL and aVF.

Results.

The complete sets of tracings from these experiments are shown in Plates 24 to 27.

(a) Standard leads.

The results in the standard leads were as might be expected. At stage 2 (10,000 ohms total) there was no obvious difference from the control. In the subsequent stages 3 and 4 however there was a uniform reduction in the amplitude of all waves and a tendency to slurring of the various junctions. These changes were due partly to reduction in the current flow, and partly to slackening of the string. The critical resistance was in the region of 20,000 ohms.

(b) Unaugmented unipolar limb leads.

In these leads no obvious change occurred at stages 2 and 3 with the lower order of resistances. At stage 4 however when the total resistance was 16,600 ohms, there was diminution in amplitude of the deflections and some slurring as in the equivalent standard leads.

(c) Augmented unipolar limb leads.

In contrast to the results in the standard and unaugmented unipolar leads striking changes were observed in the experiments in the augmented unipolar limb leads.

Lead aVR: experiment A.

The tracing obtained at stage 1 with the 5,000 ohm resistances showed slight reduction in the amplitude of the deflections as compared with the control Goldberger lead with no resistance. The tracings at stages 2 and 3, where the total circuit resistance was still relatively small, were identical with that of stage 1. In the subsequent stages 4, 5 and 6, where the total resistance was increasingly greater than 20,000 ohms, the tracings showed a progressive decrease in amplitude and slurring due to the causes previously mentioned.

Lead aVR: experiment B.

When the left arm wire was at no resistance and 5,000 ohms were added to the left leg wire the tracing was immediately altered so as to be identical with an inverted lead 1. This pattern was retained through the subsequent series of resistances.

Lead aVR: experiment C.

When the left leg wire was at no resistance and 5,000 ohms were added to the left arm wire, the resulting tracing was identical with an inverted lead 11, and this pattern was retained through the subsequent series of resistances.

Lead aVL: experiment A.

The results were the same as for the aVR lead.

Lead aVL: experiment B.

When the right arm wire was at no resistance and 5,000 ohms were added to the left leg wire, the tracing immediately resembled lead 1, and with 10,000 ohms it was identical with lead 1. This pattern was retained through the subsequent series of resistances.

Lead aVL: experiment C.

When the left leg wire was at no resistance, and 5,000 ohms were added to the right arm wire, the tracing became identical with an inverted lead 111. This pattern was retained through the subsequent series of resistances.

The changes in lead aVL were particularly obvious as they entailed a reversal in polarity of the P and T waves.

Lead aVF: experiment A.

The results obtained were the same as for aVR and aVL.

Lead aVF: experiment B.

When the right arm wire remained at no resistance and 5,000 ohms were added to the left arm wire, the tracing became identical with lead 11 and this pattern was retained throughout the subsequent series of resistances.

Lead aVF: experiment C.

When the left arm wire remained at no resistance and 5,000 ohms were added to the right arm wire, the tracing became identical with lead 111. This pattern was retained throughout the subsequent series of resistances.

Conclusions.

With the string galvanometer a total external resistance of approximately 15,000 ohms can be added to the circuit without affecting the accuracy of the tracing. With greater resistances than this accuracy is rapidly lost.

With the three point central terminal for recording unaugmented extremity potentials, equal resistances of approximately 30,000 ohms can be added to each limb without impairment of accuracy as the total equivalent resistance is still only 10,000 ohms. The original value of 5,000 ohms chosen by Wilson gives an equivalent total resistance of 5,000/3 ohms i.e. 1,600 ohms approximately, which is well within the safety limit.

For the two point terminal used in recording the augmented unipolar extremity potentials, equal resistances of 20,000 ohms may be added to each limb without loss of accuracy as the total increase of external resistance is now 20,000/2 ohms i.e. 10,000 ohms. When values of 5,000 ohms are chosen the equivalent external resistance is 2,500 ohms which is again well within the accuracy margin.

From the results of experiments B and C however, it is obvious that differences in the resistances in the two branches of the central terminal can have a very significant effect on the augmented unipolar extremity leads. These differences are predictable on theoretical grounds as follows:-

aVR is converted to an inverted lead 1 or an inverted lead 11 depending on whether the left leg or left arm branch of the terminal respectively is blocked.

aVL is converted to an upright lead 1 or an inverted lead 111 depending on whether the left leg or right arm branch of the terminal respectively is blocked.

aVF is converted to an upright lead 11 or an upright lead 111 depending on whether the left arm or right arm branch of the terminal respectively is blocked.

The reason for some of the leads being upright while others are inverted lies in the different connections to the galvanometer of the actual standard leads and those produced as a result of the experiments.

It had originally been thought that relatively large resistances would be required to produce such results, but actual experiment shows that a difference of only 5,000 ohms is required in an average case. It can therefore be deduced that differences considerably less than 5,000 ohms may also produce significant alterations.

Differences in skin resistance of the order of 1,000 to 3,000 ohms are not uncommonly encountered in ordinary practice. Such differences are of no great moment in bipolar leads such as the standard limb leads, as the resistances are in series and uniformity of results is obtained by appropriate standardisation for each lead. With a two point leading system however, such as the central terminal for augmented extremity leads, these different resistances are in parallel and distortion of the tracing is immediately produced. The important factor is the difference in the resistances and not whether the resistances themselves are actually low or high. In fact the higher they are the less chance is there of distortion if the difference remains constant.

Such considerations lead to the conclusion that the apparently vagarious discrepancies in the augmented extremity leads obtained with and without 5,000 ohm resistances in the central terminal are actually due to differences in skin electrode resistances. Such differences are minimised and may even be eliminated by inclusion of suitable resistances in the central terminal and experimentally it would seem that 5,000 ohms is adequate for this purpose.

It may be noted that discrepancies of the type described are usually more obvious in the aVL lead than in the aVR and aVF leads. This is because lead aVL tends to be converted to an upright lead 1 or an inverted lead 111. Thus in normal cases at least the two aberrant leads tend to have oppositely directed P and T waves and even QRS complexes. In aVF on the other hand the two aberrant leads are unaltered in polarity and in aVR they are both reversed in polarity. Distortions are therefore usually less noticeable.

No doubt similar differences also occur in the three point terminal as used for the unaugmented extremity potentials but in this case they are rather more difficult to predict and interpret as three variables are involved instead of only two.

CASE 2.

In this case leads CRI and CFI were first taken. Lead V1 using a Goldberger central terminal with no resistance in its branches was then recorded. Thereafter the right arm branch of the central terminal was kept at no resistance while the series of equal resistances was added to the left arm and left leg branches. These resistances were as follows: 5,000 ohms (A), 10,000 ohms (B), 20,000 ohms (C), 100,000 ohms (D), 500,000 ohms (E) and 1 megohm (F). Tracings were taken at each stage. The left leg branch was then put at no resistance while the right arm and left arm branches were put at 5,000 ohms and a further tracing (G) was taken.

Similar experiments were repeated for precordial positions 3 and 5.

Results.

The complete series of tracings from these experiments is shown in Plate 28.

The effect of adding equal resistances to the left arm and left leg branches of the central terminal was to convert the V lead in each case to the CR lead. It was found that 5,000 ohms was sufficient to accomplish this and the pattern remained unaltered through the subsequent series of resistances.

Similarly the addition of 5,000 ohms to the right arm and left arm branches of the terminal sufficed to convert the V lead to the corresponding CF lead. The differences in this instance were particularly obvious in the P wave which was altered from upright to inverted.

Conclusions.

From this experiment it can be seen that relatively small differences in the resistances in the branches of the central terminal can produce significant alterations in the form of the unipolar chest leads. In practice therefore it can be concluded that similar discrepancies may occur due to differences in skin electrode resistance in the limbs. Such discrepancies however will usually be less obvious than in the case of the unipolar extremity leads because (1) the precordial deflections are relatively so much larger and therefore less liable to noticeable distortion and (2) three possible variables are involved instead of two.

As with the unipolar extremity potentials the inclusion of 5,000 ohm resistances in the branches of the central terminal will minimise the effect of any inequalities in skin resistance.

General conclusions.

When the string galvanometer is employed the method of choice for recording the unipolar precordial leads is a central terminal of the original Wilson type with 5,000 ohm resistances included.

For the extremity potentials, the augmented method on the principle of Goldberger is to be recommended but here it is even more important to retain the 5,000 ohm resistances in the branches of the terminal.

SECTION 8.

Comparison of the V, CR, CL and CF Precordial Leads.

The object of the investigations described in the present section was to determine the significance of the differences between the unipolar and the three bipolar types of chest lead.

Method.

A total of sixty cases was studied, of which thirty were normal subjects and thirty were abnormal.

Unipolar leads and bipolar leads CR, CL and CF were taken from each of the precordial positions 1 to 6. The electrode holder and switching device were used to facilitate the recording of these leads. All the records were taken with the subject in the recumbent posture.

Results.

The complete series of tracings from these cases are shown in plates 29 to 88 with their accompanying descriptions.

The cases in both the normal and the abnormal groups have been arranged according to the electrocardiographic position of the heart. Thus in the normal group, cases 1 to 8 are vertical, cases 9 to 17 are semi-vertical, cases 18 to 21 are intermediate, cases 22 to 25 are semi-horizontal, and cases 26 and 27 are horizontal. The other three normal hearts are cases 1 to 3 of section 9, cases 1 and 2 being semi-vertical and case 3 semi-horizontal.

In the abnormal group, cases 28 to 32 are vertical, cases 33 to 38 are semi-vertical, cases 39 and 40 are intermediate, cases 41 to 43 are semi-horizontal, cases 44 to 48 are horizontal, and case 49 is indeterminate. The other eight abnormal hearts are cases 4 to 11 of section 9, case 4 being vertical, cases 5 to 7 being semi-vertical, cases 8 and 11 being intermediate, and cases 9 and 10 being horizontal.

Differences between the various types of lead are evident in all cases. These differences can affect any of the constituent parts of the tracing - P wave, QRS complex, S-T segment, T wave or U wave. In some cases minor features of the tracing, such as notching of the QRS complex, are also affected.

In each individual case the differences remain constant through all the precordial positions. In the normal cases therefore the effect is usually most obvious in the extreme right (1 and 2) or left (5 and 6) positions where the amplitude of the deflections tends to be smallest and therefore most liable to noticeable distortion. In many of the abnormal cases however the differences are most obvious in the transitional zone (3, 4 and 5) where the polarity of the deflections is changing. This is well seen in the cases of bundle branch block and left ventricular strain (e.g. cases 32, 39, 45 and 46). In the cases of myocardial infarction the differences are most obvious at the edges of the infarct where again the polarity of the waves is changing (e.g. cases 43 and 47).

In the normal cases the P wave, QRS complex and T wave are invariably most positive in the CR leads. The P wave and T wave are usually most negative in the CF leads. The QRS complex is most negative in either the CL or CF leads depending on the position of the heart. Thus with a vertical heart and right axis deviation the QRS complex is most negative in the CF leads; with a horizontal heart and left axis deviation it is most negative in the CL leads.

In the abnormal cases the differences between the CR, CL and CF leads are influenced by the nature and site of the cardiac lesion, as well as by the position of the heart. The deflections in the CR leads are not necessarily the most positive as can be seen in the cases of bundle branch block and essential hypertension with left ventricular strain (e.g. cases 32, 39, 44, 45 and 46). The P and T waves are usually most negative in the CF leads but there are frequent exceptions.

In every case the V leads are intermediate between the extremes of the CR, CL and CF leads.

This applies to all component deflections, namely the P wave, QRS complex, S-T segment, T wave and U wave.

The amplitudes of the deflections in the four types of lead were measured in each case to the nearest 0.2 millivolts. For each deflection the mean of the CR, CL and CF values was obtained. This was found to be very close to the observed value of the corresponding deflection in the V lead. The detailed measurements for each case are shown in Tables 49 to I08 (Appendix D).

Statistical Analysis.

To ascertain whether the value of (CR+CL+CF)/3 differed significantly from that of V, statistical tests were applied to the values of the P,R,S and T waves in the same group of twenty-six normal cases included in the statistical analysis already given in Section 5.

In Table B, mean values and standard deviations of measures d where $d = V - (CR+CL+CF)/3$ are shown. The results of the t-tests indicate that the mean values differ significantly from zero at the five per cent level in only three instances namely the P wave in position I, the T wave in position 2 and the S wave in position 4. From these findings it is justifiable to conclude that the values of V and (CR+CL+CF)/3 do not differ significantly for any of the waves in any of the six positions.

TABLE B

Mean values and standard deviations of measures d of 26 normal individuals for six positions where $d = V - (CR + CL + CF)/3$

POSITION / WAVE	I		2		3		4		5		6	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
P	0.IO4*	0.I26	0.03I	0.I47	0.023	0.287	-0.033	0.I75	-0.008	0.I45	-0.042	0.I53
R	-0.067	0.5I4	-0.305	0.740	-0.298	0.92I	-0.I75	I.34	-0.07I	I.04	-0.078	I.09
S	0.007	I.IO	0.II5	I.0I	0.252	I.07	0.330*	0.625	0.049	0.245	-0.022	0.265
T	0.I59	0.453	-0.247*	0.542	-0.I30	0.548	0.I36	0.5I9	0.022	0.437	0.064	0.4II

Mean values marked * are those which a t-test gives significantly different from zero at the 5% level.

S.D. signifies standard deviation.

Conclusions.

In both normal and abnormal cases the site of the remote electrode may have a considerable effect on the form of the precordial electrocardiogram.

The CR leads tend to be the most positive; either the CL or CF leads may be the most negative depending on the position of the heart. These relationships may be altered by various types of cardiac lesion.

In every case the V leads represent the mean of the three bipolar leads. They are not affected to any extent by the position of the heart in normal cases. In abnormal cases they give a truer picture of the nature and site of the underlying cardiac lesion.

These conclusions are supported by a statistical analysis of the data in the normal cases.

SECTION 9.

Comparison of the V, CR, CL and CF Leads from Additional Chest Positions.

Though the results described in Section 8 were significant as regards the general relationship of the four types of chest lead it was considered that further information might be derived from additional leads encircling the chest. In particular it was hoped by this method to obtain a comprehensive view of the various electrocardiographic patterns from leads facing not only the anterior but also the lateral and posterior surfaces of the heart.

Method.

The V, CR, CL and CF leads were taken from a series of fifteen positions encircling the chest as follows:- Positions 1 and 2; Positions 3 to 8 on the left side of the chest; Positions 3R to 8R on the right side of the chest; and Position 9 in the vertebral line at the same level as Position 8. All the tracings were made in the recumbent position, the electrodes being applied to the back of the chest through the window in the examining table described in Section 2, Part 1V. Ten cases were studied in this way, three normal and seven abnormal. An additional case of left-sided pleurisy with effusion was examined on three separate occasions with leads from Positions 1 to 6 and 3R to

6R; two paracenteses were carried out and tracings were taken before and after the first paracentesis and after the second.

In all of these cases standard leads and unipolar limb leads were also taken.

Results.

The complete series of tracings from the first ten cases are shown in plates 78 to 87, with their accompanying descriptions. Each plate has two parts, (a) containing the standard and unipolar limb leads and chest leads from Positions 1 to 6 and (b) containing the chest leads from Positions 7 to 3R.

In general the differences between the four types of chest lead are similar to those already described in Section 8. The differences in Positions 7 to 3R are much more obvious however. This is due to two factors, (a) the relatively small size of the deflections which renders them more liable to distortion and (b) the changing QRS and T wave patterns which are encountered.

Normal QRS patterns.

The QRS complex is most positive in the CR leads and this prevents the development of any significant Q or QS pattern in these leads. In two of the three cases in fact Q is absent throughout (cases 1 and 3).

The QRS complex is most negative in the CF leads and Qr, QR and QS patterns are present in leads from the back of the chest.

The QRS patterns in the V leads are intermediate between these two extremes.

In the three cases studied the patterns in the CL leads resemble those in the V leads fairly closely.

Normal T wave patterns.

These are most positive in the CR leads and a negative T wave does not occur in any position.

They are least positive in the CF leads and negative or flat T waves occur in practically every position.

The T waves in the V leads are intermediate between the extremes of the CR and CF leads.

The T waves in the CL leads resemble fairly closely those in the V leads.

In the region of positions 7R to 6R the CF lead is an almost exact inversion of the CR lead.

Abnormal QRS patterns.

These are influenced considerably by the nature and site of the cardiac lesion.

The QRS complex is usually most positive in the CR leads and this prevents the development of any significant Q or QS pattern. A notable exception may occur in posterior myocardial infarction where the CF leads can be most positive (case 10).

The QRS complex is usually most negative in the CF leads and Qr, QR and QS patterns are therefore frequently encountered. A notable exception is posterior myocardial infarction where the CL leads tend to be most negative (cases 9 and 10).

In every case the QRS patterns in the V leads are intermediate between the extremes of the other leads.

Abnormal T wave patterns.

These are influenced considerably by the nature and site of the cardiac lesion.

Thus in the case of combined heart strain (case 6) the T wave is most positive in the CF leads and an inverted T wave does not occur after position 7; it is least positive in the CR leads and is inverted in positions 7 to 6R.

In the case of anterior myocardial infarction (case 7) the T wave is most positive in the CL leads and is not inverted in any position; it is least positive in the CF leads and is inverted in positions 8 to 3R.

In the two cases of posterior myocardial infarction (cases 9 and 10) the T wave is most positive in the CF leads and an inverted T wave does not occur in any position; it is least positive in the CL leads and is inverted in all positions.

The T wave in the V leads in every case is intermediate between the extremes of the other leads.

Similar differences occur between the various types of lead with respect to deviation of the S-T segment.

Another interesting finding is that in the region of positions 8R to 6R the CF lead is an almost exact inversion of the CR lead.

Conclusions.

The differences between the V, CR, CL and CF leads from positions 7 to 3R are in general similar to those already described for positions 1 to 6. They are however much more obvious due to (a) the smaller size of the deflections and (b) the changing patterns which are encountered.

In the normal cases the CR leads are most positive and either the CL or CF leads are least positive depending on the position of the heart.

In the abnormal cases the nature and site of the cardiac lesion play an important part in determining the differences between the various patterns.

The V leads in every case are intermediate between the extremes of the other leads. In the normal cases they are not unduly influenced by the position of the heart; in the abnormal cases they give a truer picture of the nature and site of the cardiac lesion.

Serial tracings on a case of Left-sided Pleural Effusion, with displacement of the heart to the right.

In this case standard leads, unipolar limb leads and chest leads of the V, CR, CL and CF types from positions 1 to 6 and 3R to 6R were taken. The first series was recorded immediately before and the second series immediately after removal of two pints of fluid from the left pleural cavity; the third series was taken three days later after removal of a further two pints. The tracings were all made in the semi-recumbent position.

Results.

The three sets of tracings from this case are shown in plates 88 to 90. In each set the differences between the four types of chest lead remain constant. The P wave, QRS complex and T wave are all most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

The standard leads and unipolar limb leads show little or no change after the paracenteses apart from slight increase in voltage of the T waves.

The leads over the right side of the chest show some decrease in voltage after the paracenteses. Leads over the left side of the chest show a considerable increase in voltage of both the QRS complex and the T wave, particularly after the second paracentesis.

The changes after paracentesis may be due partly to a slight shift of the heart to the left. It is more likely however that they are mainly due to a reduction in the short-circuiting activity of the fluid in the left pleural sac.

SECTION 10.

Correlation of the V, CR, CL and CF Chest Leads with the Unipolar Extremity Potentials.

In the previous sections the chest leads and the unipolar limb leads have been treated separately and the differences between the V, CR, CL and CF leads have been considered on an empirical basis. Theoretically however it should be possible to predict the differences between the four types of chest lead from a consideration of the unipolar chest and extremity leads. Thus the leads should satisfy the following equations:-

$$CR = V - VR \quad \text{.....................(1)}$$

$$CL = V - VL \quad \text{.....................(2)}$$

$$CF = V - VF \quad \text{.....................(3)}$$

It has also been shown that theoretically the sum of the three extremity potentials should be zero:-

$$VR + VL + VF = 0 \quad \text{................(4)}$$

$$\text{Therefore, } V = \frac{CR + CL + CF}{3} \quad \text{...............(5)}$$

The validity in practice of equations (4) and (5) has been discussed in sections 5 and 8 respectively.

The object of this section was to determine whether the relationships expressed in equations (1), (2) and (3) existed in practice.

Method.

The subjects of this analysis were the sixty cases already described in Section 8. In all of them the augmented unipolar extremity leads and chest leads of the V, CR, CL and CF type from positions 1 to 6 were recorded.

The amplitude of the deflections in each lead was measured to the nearest 0.2 mm. The value for the QRS complex was obtained by algebraic summation of its constituent deflections. Where diphasic P and T waves occurred the resultant value was obtained again by algebraic summation. The values of the augmented extremity potentials were multiplied by 2/3 to obtain the actual extremity potential. The values of CR, CL and CF were then calculated from the observed values of V and the appropriate extremity potential. These were compared with the observed values of CR, CL and CF.

Results.

The complete series of tracings from these cases are shown in plates 29 to 88, with their accompanying descriptions.

On examination of the tracings it is obvious in every case that the differences between the bipolar CR, CL and CF leads and the unipolar V leads are determined by the unipolar extremity potentials. Thus in the normal cases the deflections in the CR leads are invariably more positive than those in the V leads due to the uniformly negative potentials of VR.

With regard to CL and CF the differences depend on normal variations in the position of the heart as follows:-

(a) <u>Vertical position.</u>

The CL leads are more positive than the V leads due to the negative potentials in VL.

The CF leads are less positive than the V leads due to the positive potentials in VF.

(b) <u>Semi-vertical position.</u>

The CL leads closely resemble the V leads due to the small potentials in VL.

The CF leads are less positive than the V leads due to the positive potentials in VF.

(c) <u>Horizontal position.</u>

The CL leads are less positive than the V leads due to the positive potentials in VL.

The CF leads are more positive than the V leads due to the negative potentials in VF.

(d) <u>Semi-horizontal position.</u>

The CL leads are less positive than the V leads due to the positive potentials in VL.

The CF leads closely resemble the V leads due to the small potentials in VF.

The following general rule can be applied to every case:-

A positive extremity potential causes the corresponding bipolar chest lead to be less positive than the V lead; a negative extremity potential has the opposite effect.

This is in accordance with the equations (1), (2) and (3).

The same rule is applicable to the abnormal cases though the differences between the various types of lead are influenced by the nature of the cardiac lesion as well as by the position of the heart.

The calculated and observed values for the mean QRS and T deflections in the CR, CL and CF leads in the thirty normal cases are shown in table C along with the mean differences. Similar values for the thirty abnormal cases are shown in table D. A close agreement exists between the observed and calculated values of the bipolar chest leads.

<u>Conclusions</u>.

The differences between the unipolar chest leads and the bipolar CR, CL and CF leads are determined by the unipolar extremity potentials.

From a consideration of the unipolar limb and chest leads it is possible to predict accurately the CR, CL and CF lead patterns.

TABLE C

Observed values of the unipolar limb and chest leads, calculated and observed values of the bipolar chest leads and the differences (calculated less observed), for the mean QRS and T deflections in 30 normal subjects

	QRS						T					
VR observed	-4.0						-I.37					
VL observed	0.3						0.I9					
VF observed	3.8						I.20					
	Precordial Position						Precordial Position					
	I	2	3	4	5	6	I	2	3	4	5	6
V observed	-3.0	-II.7	-0.7	9.6	I0.4	8.8	I.35	5.58	5.9I	4.47	3.44	2.43
CR calculated	I.0	-7.7	3.3	I3.6	I4.4	I2.8	2.72	6.95	7.28	5.84	4.8I	3.80
CR observed	0.3	-8.2	3.2	I2.4	I4.0	I2.5	2.4I	6.55	6.94	5.7I	5.03	3.69
Difference	0.7	0.5	0.I	I.2	0.4	0.3	0.3I	0.40	0.34	0.I3	-0.22	0.II
CL calculated	-3.3	-I2.0	-I.0	9.3	I0.I	8.5	I.I6	5.39	5.72	4.28	3.25	2.24
CL observed	-4.I	-I3.3	-0.9	8.7	9.9	8.6	I.37	4.94	5.4I	4.46	3.I3	2.I6
Difference	0.8	I.3	-0.I	0.6	0.2	-0.I	-0.2I	0.45	0.3I	-0.I8	0.I2	0.08
CF calculated	-6.8	-I5.5	-4.5	5.8	6.6	5.0	0.I5	4.38	4.7I	3.27	2.24	I.23
CF observed	-8.0	-I6.9	-4.0	5.6	6.2	4.I	0.40	3.98	4.66	3.II	2.47	0.99
Difference	I.2	I.4	-0.5	0.2	0.4	0.9	-0.25	0.40	0.05	0.I6	-0.23	0.24

TABLE D

Observed values of the unipolar limb and chest leads, calculated and observed values of the bipolar chest leads and the differences (calculated less observed), for the mean QRS and T deflections in 30 abnormal subjects

	QRS						T					
VR observed	-4.4						-0.62					
VL observed	2.0						-0.I9					
VF observed	2.3						0.84					
	Precordial Position						Precordial Position					
	I	2	3	4	5	6	I	2	3	4	5	6
V observed	-II.8	-II.4	-3.9	6.5	II.7	9.3	3.24	5.52	3.99	2.3I	0.89	0.4I
CR calculated	-7.4	-7.0	0.5	I0.9	I6.I	I3.7	3.86	6.I4	4.6I	2.93	I.5I	I.03
CR observed	-6.8	-7.4	-0.7	I0.9	I5.8	I3.I	3.58	5.77	4.58	3.I0	I.50	I.I7
Difference	-0.6	0.4	I.2	0.0	0.3	0.6	0.28	0.37	0.03	-0.07	0.0I	-0.I4
CL calculated	-I3.8	-I3.4	-5.9	4.5	9.7	7.3	3.43	5.7I	4.I8	2.50	I.08	0.60
CL observed	-II.7	-II.9	-5.I	5.0	9.4	8.I	3.58	5.57	4.II	2.55	I.08	0.75
Difference	-2.I	-I.5	-0.8	-0.5	0.3	-0.8	-0.I5	0.I4	0.07	-0.05	0.0	-0.I5
CF calculated	-I4.I	-I3.7	-6.2	4.2	9.4	7.0	2.40	4.68	3.I5	I.47	0.05	-0.43
CF observed	-I3.I	-I3.8	-6.0	4.9	9.3	7.9	2.3I	4.6I	3.34	I.69	0.24	-0.57
Difference	-I.0	0.I	-0.2	-0.7	0.I	-0.9	0.09	0.07	-0.I9	-0.22	-0.I9	0.I4

PART 11.

THE ELECTROCARDIOGRAM IN HEALTH.

PART 11.

The Electrocardiogram in Health.

SECTION 1.

Historical review and method of investigation.

Normal values for the three standard limb leads have been well established by such investigators as Lewis and Gilder (1912), Jensen et al.(1932), Chamberlain and Hay (1939), Pardee (1941) and Stewart and Manning (1944). Much work has also been done in the past on the normal patterns of certain of the bipolar chest leads, such as leads IVR and IVF, by Katz and Kissin (1933), Master (1934), Shipley and Hallaran (1936), Wood and Selzer (1939) and Hoskin and Jonescu (1940). Adequate studies of the normal unipolar limb and chest leads however are relatively few in number. Thus Kossmann and Johnston (1935) described the appearances of the unaugmented unipolar limb leads and of chest leads V1 to V5 in a series of thirty healthy young men. For the augmented unipolar limb leads Goldberger (1942b) gave average values based on an unspecified number of normal cases. More recently Myers et al.(1947) have listed their findings in a series of normal hearts for the standard leads, the augmented unipolar limb leads and chest leads V1 to V6. As theirs was primarily an autopsy correlation however the ages of the majority of their cases lay in the fourth to the seventh decades. In their comparative studies, Dolgin et al.(1949a) and Leatham (1950) have also included ranges and average values for leads V1 to V7 in their normal series of 44 and 100 cases respectively.

The normal patterns of unipolar leads in general have been classified by Goldberger (1949a) on theoretical grounds as follows:-

1. Leads which face the epicardial surface of the left ventricle.

   These have a qR pattern and T is usually upright. They may occasionally have an R or a qRs pattern.

2. Leads which face the epicardial surface of the right ventricle.

   These have an rS or RS pattern and T is usually upright but may sometimes be inverted. An rSr' pattern is occasionally found.

3. Leads which face the cavity of the right ventricle.

   These have an rS pattern and T is inverted. Sometimes a QS pattern may appear.

4. Leads which face the cavity of the left ventricle.

   These have a QS pattern and T is inverted.

5. Leads which face the back of the heart.

   These have a QR pattern and T is inverted. Sometimes a Qr or a qR pattern may appear.

The objects of the present work were (a) to determine values for the standard leads, unipolar limb leads and unipolar chest leads V1 to V6 in a representative series of normal cases and (b) to obtain practical confirmation of the theoretical unipolar lead patterns.

Method.

Standard limb leads, unipolar limb leads and unipolar chest leads VI to V6 were recorded in sixty healthy adults of whom fifty-two were males and eight were females. The records were taken with the subject in the recumbent posture and at least two hours after the previous meal.

Age distribution of cases.

Ages ranged from I5 to 62 years the average being 29 years. The age distribution by decades is shown in Table I.

TABLE I

Age distribution of sixty healthy adults

Decade	2nd	3rd	4th	5th	6th	7th
No.of cases	I5	24	II	6	2	2

Measurement.

The amplitudes of the various waves in each lead were measured to the nearest 0.2 mm. The individual measurements for each case are shown in Tables IO9 to I68 (Appendix D).

The nomenclature of the various waves and the method of measurement were as already described in Part I, Section 2. The results of the analyses are presented in the form of distribution tables in the text (Tables II to XXVIII). In these tables zero values are treated as a separate class. Positive values for any particular class interval include those of its upper limit and negative values for any particular class interval include those of its lower limit. Thus if the class interval is I mm. a value of plus I mm. is included in the O to I class and a value of minus I mm. is included in the -I to O class.

SECTION 2.

Standard Limb Leads.

In this section the measurements and appearances of the waves in the standard limb leads are analysed. The results for the P,Q,R,S and T waves are shown in distribution tables.

P wave.

TABLE II

Height of P wave in sixty healthy adults

Height of P in mm.	I	II	III
I.5 to 2.0	0	5	0
I.0 to I.5	I	2I	2
0.5 to I.0	33	27	27
0 to 0.5	26	6	23
0	0	I	3
-0.5 to 0	0	0	5
Mean height	0.54	0.94	0.4I

The height of the P wave showed least variation in lead I and it was never diphasic, flat or inverted in this lead. In lead II the P wave was diphasic in two cases the resultant value being positive in one case and zero in the other; it was never flat or inverted in this lead. Both the height and the form of the P wave showed the most variation in lead III. In this lead it was diphasic in eight cases, flat in two cases and inverted in two cases. Four of the diphasic P waves had resultant positive values, one had a resultant zero value and three had resultant negative values.

<u>Q wave.</u>

TABLE III

Depth of Q wave in sixty healthy adults

Depth of Q in mm.	I	II	III
4 to 5	0	0	2
3 to 4	0	0	I
2 to 3	0	I	0
I to 2	2	8	4
0 to I	28	29	27
0	30	22	26
Mean depth	0.24	0.45	0.53

A Q wave was present in all three leads in twelve cases; in leads I and II in nine cases; in leads II and III in seventeen cases; in lead I alone in nine cases and in lead III alone in five cases. It was absent in all three leads in eight cases.

R wave.

TABLE IV

Height of R wave in sixty healthy adults

Height of R in mm.	I	II	III
I8 to 20	0	I	I
I6 to I8	0	3	I
I4 to I6	0	6	2
I2 to I4	0	6	4
I0 to I2	0	I4	4
8 to I0	4	I5	5
6 to 8	I3	9	I5
4 to 6	2I	3	7
2 to 4	I8	3	9
0 to 2	4	0	I2
0	0	0	0
Mean height	4.83	I0.23	6.43

The R wave was never absent in any of the three leads in any of the sixty cases.

S wave.

TABLE V

Depth of S wave in sixty healthy adults

Depth of S in mm.	I	II	III
4 to 6	3	2	3
2 to 4	8	I3	II
0 to 2	39	35	25
0	I0	I0	2I
Mean depth	I.22	I.45	I.I9

An S wave was present in all three leads in twenty-nine cases; in leads I and II in fourteen cases; in leads II and III in seven cases; in leads I and III in one case; in lead I alone in six cases and in lead III alone in two cases. It was absent in all three leads in one case.

Configuration of the QRS complex.

The only noteworthy feature was the presence of an RSR' pattern in leads II and III in one case and in lead III alone in five cases.

T wave.

TABLE VI

Amplitude of T wave in sixty healthy adults

Amplitude of T in mm.	I	II	III
6 to 7	0	2	0
5 to 6	0	I	0
4 to 5	3	8	0
3 to 4	I	20	I
2 to 3	I9	I6	I0
I to 2	26	I2	I9
0 to I	II	I	25
0	0	0	I
-I to 0	0	0	4
Mean amplitude	I.82	3.05	I.I3

The T wave was always upright in leads I and II. In lead III the T wave was inverted in three cases and diphasic in three cases. One of the diphasic T waves had a resultant positive value, one had a resultant zero value and one had a resultant negative value.

Comment.

In general the results agree fairly closely with those of previous observers. There are however two noteworthy differences.

(a) The amplitude of the P waves in leads II and III tends to be lower in the present series.

(b) The values of the T waves in leads II and III tend to be more positive in the present series. This is particularly obvious in lead III where in the present series of sixty cases only three have diphasic T waves and three have inverted T waves, and the amount of inversion does not exceed I mm. This is in contrast to the fifty-two cases of Lewis and Gilder (I9I2) of which six had diphasic T waves in lead III and eight had inverted T waves in lead III and the amount of inversion was as great as 2mm.

The explanation of these differences presumably lies in the fact that in the present series all the tracings were taken with the subject in the recumbent posture. Had the tracings been taken in the sitting or in the semi-recumbent posture the values of the P waves in leads II and III would have been more positive and those of the T waves in leads II and III would have been less positive. This is fully borne out by the results of the postural experiments on normal subjects described in Part IV of this thesis.

SECTION 3.

Unipolar Limb Leads.

In this section the measurements and appearances of the waves in the augmented unipolar limb leads are analysed. In forty-five of the sixty cases the augmented extremity potentials were recorded. In the remaining fifteen cases the unaugmented extremity potentials were recorded and the values in these cases were multiplied by 3/2 to render them comparable.

QRS complex.

With regard to the QRS complex, a preliminary survey of the data indicated that, in view of the variety of the patterns encountered, an analysis of these patterns was more likely to be of value than an analysis of the individual waves.

In describing the patterns the following arbitrary standard was adopted. In any complex the wave of greatest amplitude was assigned a capital letter. Other waves if present were signified by capital or small letters depending on whether their values were 30 per cent or more of the value of the wave of greatest amplitude or less than 30 per cent of this value respectively. An exception to this rule was made where the value of the greatest wave was less than I mm.; in such cases small letters alone were used.

The heart was considered to be vertical or horizontal according to the appearances in leads aVL and aVF.

(a) Vertical.

The heart was considered to be vertical with forward rotation of the apex when an initial negative deflection succeeded by a positive deflection was present in lead aVF but not in aVL.

The heart was considered to be vertical with backward rotation of the apex when neither lead aVL nor lead aVF had an initial negative deflection succeeded by a positive deflection.

(b) Horizontal.

The heart was considered to be horizontal with forward rotation of the apex when an initial negative deflection succeeded by a positive deflection was present in both lead aVL and lead aVF.

The heart was considered to be horizontal with backward rotation of the apex when an initial negative deflection succeeded by a positive deflection was present in lead aVL but not in lead aVF.

The distribution of cases according to this classification is shown in Table VII.

TABLE VII

Distribution of vertical and horizontal hearts in sixty healthy adults.

	Vertical	Horizontal
Forward rotation of apex	27	4
Backward rotation of apex	8	2I
Total	35	25

The patterns in the individual leads are now considered separately.

Lead aVR.

In the vertical hearts irrespective of whether forward or backward rotation of the apex is present there are four main types of pattern.

(I) Three cases have an rS pattern.

(2) Eleven cases have an rSr' pattern and one case has an rSR' pattern.

(3) Six cases have a QS pattern.

(4) Ten cases have a Qr pattern and four cases have a QR pattern.

In the horizontal hearts irrespective of whether forward or backward rotation of the apex is present there are three main types of pattern.

(I) Twelve cases have an rSr' pattern.

(2) Three cases have a QS pattern.

(3) Six cases have a Qr pattern and four cases have a QR pattern.

Lead aVL.

In the vertical hearts irrespective of whether forward or backward rotation of the apex is present there are three main types of pattern.

(I) Two cases have an R pattern; one case has an Rs pattern; fourteen cases have an RS pattern; twelve cases have an rS pattern.

(2) Two cases have an rSr' pattern and one case has an RSR' pattern.

(3) Three cases have a QS pattern.

In the horizontal hearts irrespective of whether forward or backward rotation of the apex is present there are two main types of pattern.

(I) Seven cases have a qR pattern; five cases have a qRs pattern; three cases have a qRS pattern; two cases have a qRsR' pattern; one case has a qrS pattern; one case has a qrs pattern.

(2) One case has a QRS pattern; one case has a QRs pattern; three cases have a QR pattern; one case has a Qr pattern.

<u>Lead aVF.</u>

In the vertical hearts with forward rotation of the apex there is only one main type of pattern. Thus eleven cases have a qR pattern and sixteen cases have a qRs pattern.

In the vertical hearts with backward rotation of the apex there is only one main type of pattern. Thus three cases have an R pattern; four cases have an Rs pattern; one case has an RS pattern.

In the horizontal hearts with forward rotation of the apex there is only one main type of pattern. Thus two cases have a qRs pattern and two cases have a qRS pattern.

In the horizontal hearts with backward rotation of the apex there are two main types of pattern.

(I) Five cases have an R pattern; one case has an Rs pattern; twelve cases have an RS pattern; one case has an rS pattern.

(2) One case has an Rsr' pattern and one case has an RsR' pattern.

A noteworthy feature is that in the present series a Q wave does not occur in any case i.e. an initial negative deflection if present never reaches 30 per cent of the subsequent positive deflection.

P wave.

The results for the P waves are shown in distribution tables.

TABLE VIII

Amplitude of P wave in sixty healthy adults

Amplitude of P in mm.	aVR	aVL	aVF
I.5 to 2.0	0	0	I
I.0 to I.5	0	0	7
0.5 to I.0	0	2	33
0 to 0.5	0	27	I6
0	0	I2	3
-0.5 to 0	I5	I8	0
-I.0 to -0.5	42	I	0
-I.5 to -I.0	2	0	0
-2.0 to -I.5	I	0	0
-2.5 to -2.0	0	0	0
Mean amplitude	-0.72	0.05	0.70

An analysis of the results in the vertical and horizontal groups is shown in Table IX.

TABLE IX

Amplitude of P wave in sixty healthy adults

	VERTICAL (35 cases)			HORIZONTAL (25 cases)		
Amplitude of P in mm.	aVR	aVL	aVF	aVR	aVL	aVF
I.5 to 2.0	0	0	I	0	0	0
I.0 to I.5	0	0	5	0	0	2
0.5 to I.0	0	2	I9	0	0	I4
0 to 0.5	0	I3	9	0	I4	7
0	0	6	I	0	6	2
-0.5 to 0	8	I3	0	7	5	0
-I.0 to -0.5	24	I	0	I8	0	0
-I.5 to -I.0	2	0	0	0	0	0
-2.0 to -I.5	I	0	0	0	0	0
Mean amplitude	-0.74	0.0I	0.75	-0.66	0.II	0.6I

In the present series the P wave is never negative in aVF and is always negative in aVR.

In aVR there is no significant difference between the vertical group and the horizontal group. In aVL however the P wave tends to be less positive in the vertical group than in the horizontal group while in aVF the reverse occurs.

T wave.

The results for the T waves are shown in distribution tables.

TABLE X

Amplitude of T wave in sixty healthy adults

Amplitude of T in mm.	aVR	aVL	aVF
4 to 5	0	0	2
3 to 4	0	0	9
2 to 3	0	I	I7
I to 2	0	II	22
0 to I	0	30	9
0	0	2	I
-I to 0	4	I5	0
-2 to -I	I9	I	0
-3 to -2	23	0	0
-4 to -3	I0	0	0
-5 to -4	3	0	0
-6 to -5	I	0	0
Mean amplitude	-2.46	0.45	2.I0

In the present series of sixty cases the T wave is always negative in aVR and never negative in aVF.

An analysis of the results in the vertical and horizontal groups is shown in Table XI.

TABLE XI

Amplitude of T wave in sixty healthy adults

	VERTICAL (35 cases)			HORIZONTAL (25 cases)		
Amplitude of T in mm.	aVR	aVL	aVF	aVR	aVL	aVF
4 to 5	0	0	I	0	0	I
3 to 4	0	0	8	0	0	I
2 to 3	0	0	I2	0	I	5
I to 2	0	8	I0	0	3	I2
0 to I	0	I6	4	0	I4	5
0	0	0	0	0	2	I
-I to 0	2	I0	0	2	5	0
-2 to -I	7	I	0	I2	0	0
-3 to -2	I7	0	0	6	0	0
-4 to -3	6	0	0	4	0	0
-5 to -4	2	0	0	I	0	0
-6 to -5	I	0	0	0	0	0
Mean amplitude	-2.66	0.42	2.37	-2.20	0.5I	I.73

In aVR the T wave tends to be more negative in the vertical group than in the horizontal group.

in aVF the T wave tends to be more positive in the vertical group than in the horizontal group. In aVL though negative and positive values are found in both groups, the T wave tends to be more positive in the horizontal group.

SECTION 4

Precordial Leads.

In this section the measurements and appearances of the waves in the unipolar precordial leads VI to V6 are analysed. For each wave a general analysis of the sixty cases as a whole is given. The cases are then divided into three groups according to the amount of rotation around the longitudinal axis as assessed by the first appearance of a qR pattern in the precordial leads. In none of the cases did this pattern appear in VI to V3. The three groups are therefore classified as follows.

(a) Moderate counter-clockwise rotation.

This is considered to be present when the qR pattern first appears in V4. There are nineteen cases in this group.

(b) Moderate clockwise rotation.

This is considered to be present when the qR pattern first appears in V5 or V6. There are twenty-nine cases in this group.

(c) Marked clockwise rotation.

This is considered to be present when the qR pattern fails to appear in any of the precordial leads.

There are twelve cases in this group.

P wave.

The results for the P waves are shown in distribution tables.

TABLE XII

Amplitude of P wave in sixty healthy adults

Amplitude of P in mm.	VI	V2	V3	V4	V5	V6
I.0 to I.5	3	I	2	0	0	0
0.5 to I.0	36	39	36	33	26	I7
0 to 0.5	I2	I8	20	25	33	4I
0	5	2	2	2	I	2
-0.5 to 0	4	0	0	0	0	0
Mean amplitude	0.58	0.63	0.62	0.56	0.5I	0.43

The P wave is inverted in VI in three cases and diphasic in eight cases. Four of the diphasic P waves have a resultant positive value, three have resultant zero value and one has a negative value. The P wave is never inverted in any of the other leads. It is diphasic in V2 in two cases and in V3 in one case; in each instance it has a resultant zero value.

A comparison of the findings in the three groups is shown in Table XIII.

TABLE XIII

Amplitude of P wave in sixty healthy adults

Amplitude of P	Moderate counter-clockwise rotation (I9 cases)						Moderate clockwise rotation (29 cases)						Marked clockwise rotation (I2 cases)					
in mm.	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6
I.0 to I.5	0	0	0	0	0	0	2	0	I	0	0	0	I	I	I	0	0	0
0.5 to I.0	IO	I2	II	II	7	4	I8	I9	I6	I2	IO	6	8	8	9	IO	9	7
0 to 0.5	6	7	8	8	I2	I5	4	8	IO	I5	I8	2I	2	3	2	2	3	5
0	I	0	0	0	0	0	3	2	2	2	I	2	I	0	0	0	0	0
-0.5 to 0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Mean amplitude	.48	.6I	.59	.59	.48	.4I	.6I	.6I	.59	.49	.46	.39	.70	.72	.76	.72	.68	.60

There are no obvious differences in the findings between the moderate counter-clockwise and moderate clockwise groups. In the marked clockwise group however there is a tendency for the P wave to be more positive than in the other two groups.

Q wave.

A Q wave is present in one or more of leads V4 to V6 in forty-eight cases. It is not present in leads VI to V3 in any of the cases though a QS pattern occurs in lead VI in one case. The distribution of the Q wave in the sixty cases is shown in Table XIV.

TABLE XIV

Depth of Q in sixty healthy adults

Depth of Q in mm.	VI	V2	V3	V4	V5	V6
2 to 3	0	0	0	0	2	3
I to 2	0	0	0	3	8	IO
0 to I	0	0	0	I6	30	33
0	60	60	60	4I	20	I4

As a general rule when the Q wave appears in any precordial lead it is present also in subsequent leads to the left. Two exceptions occur in the present series. In one case a Q wave appears in leads V4 and V5 but not in V6; in another case a Q wave appears in V5 but not in V6.

Relationship of depth of Q wave to height of R wave (Q/R ratio)

The relationship of the depth of the Q wave to the height of the R wave in the forty-eight cases where a qR pattern was present in one or more of leads V4 to V6 is shown in Table XV.

TABLE XV

Q/R ratio in forty-eight healthy adults
(Q is expressed as a percentage of R)

Q/R ratio	V4	V5	V6
I5 to 20	0	0	3
IO to I5	0	4	IO
5 to IO	2	IO	I2
under 5	I7	26	23 *

* This total includes two cases where the Q wave was absent in V6 but present in V4 and V5 and V5 respectively.

The Q/R ratio tends to increase from right to left. In no case in the present series does it exceed 20 per cent in any position.

The Q/R ratios in the moderate counter-clockwise and moderate clockwise groups are shown separately in Tables XVI and XVII.

TABLE XVI

Q/R ratio in moderate counter-clockwise group
(I9 cases)

Q/R ratio	V4	V5	V6
I5 to 20	0	0	2
I0 to I5	0	3	8
5 to I0	2	8	5
under 5	I7	8	4 *

* This includes one case where the Q wave was absent in V6 but present in V4 and V5.

TABLE XVII

Q/R ratio in moderate clockwise group
(29 cases)

Q/R ratio	V5	V6
I5 to 20	0	I
I0 to I5	I	2
5 to I0	2	7
under 5	I8	I9 *

* This includes one case where the Q wave was absent in V6 but present in V5.

In the moderate clockwise group there are eight cases in which the Q wave is present in V6 alone.

The Q/R ratio for this group is shown in Table XVIII.

TABLE XVIII

Q/R ratio in moderate clockwise group where Q first appears in V6 (8 cases)

Q/R ratio	V6
I5 to 20	0
IO to I5	0
5 to IO	I
under 5	7

From this analysis it is clear that as regards the precordial leads any consideration of the Q/R ratio alone is of little value. The other factor which must be taken into account is the lead in which the Q wave first appears.

R wave.

An R wave is present in all cases in each of the precordial leads VI to V6 with one exception. In this case a small QS deflection appears in VI. This case is one of the marked clockwise group and the depth of the QS deflection is 6.6 mm.

The distribution of the R wave in the sixty cases is shown in Table XIX.

TABLE XIX

Height of R wave in sixty healthy adults

Height of R in mm.	VI	V2	V3	V4	V5	V6
28 to 32	0	0	0	0	I	0
24 to 28	0	0	0	6	3	0
20 to 24	0	0	0	6	4	I
I6 to 20	0	I	2	9	9	7
I2 to I6	I	3	7	I8	22	I0
8 to I2	2	I2	20	I2	I6	25
4 to 8	20	28	28	9	5	I6
0 to 4	36	I6	3	0	0	I
0	I	0	0	0	0	0
Mean height	3.68	6.47	8.50	I4.7	I4.0	I0.9

The comparative distribution in the three groups of cases is shown in Table XX. No significant differences are apparent. It can be concluded therefore that in normal subjects the amount of rotation around the longitudinal axis has relatively little effect on the absolute height of the R wave in precordial leads VI to V6.

TABLE XX

Height of R wave in sixty healthy adults

Height of R in mm.	Moderate counter-clockwise rotation (I9 cases)						Moderate clockwise rotation (29 cases)						Marked clockwise rotation (I2 cases)					
	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6
28 to 32	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0
24 to 28	0	0	0	4	I	0	0	0	0	I	2	0	0	0	0	I	0	0
20 to 24	0	0	0	5	2	I	0	0	0	I	I	0	0	0	0	0	I	0
I6 to 20	0	I	I	5	6	2	0	0	I	4	2	3	0	0	0	0	I	2
I2 to I6	I	2	4	4	5	4	0	I	3	I2	I3	5	0	0	0	2	4	I
8 to I2	I	5	7	0	3	8	I	5	8	7	IO	I2	0	2	5	5	3	5
4 to 8	9	9	7	I	I	4	8	I4	I5	4	I	9	3	5	6	4	3	3
0 to 4	8	2	0	0	0	0	20	9	2	0	0	0	8	5	I	0	0	I
0	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0	0
Mean height	4.9	8.3	IO.I	I9.3	I6.5	I2.I	3.3	5.9	8.0	I3.2	I3.3	IO.6	2.6	4.8	7.3	IO.8	II.9	IO.I

S wave.

An S wave is present in every case in leads VI to V3 except in the one case previously mentioned where a QS pattern appears in lead VI. The S wave is absent in lead V4 in two cases, in lead V5 in six cases and in lead V6 in twelve cases. When the S wave disappears in any particular lead it remains absent in subsequent leads to the left.

The distribution of the S wave in the sixty cases is shown in Table XXI.

TABLE XXI

Depth of S wave in sixty healthy adults

Depth of S in mm.	VI	V2	V3	V4	V5	V6
36 to 40	0	I	0	0	0	0
32 to 36	0	I	0	0	0	0
28 to 32	0	0	0	0	0	0
24 to 28	I	2	0	0	0	0
20 to 24	0	4	3	0	0	0
I6 to 20	0	20	I0	I	0	0
I2 to I6	I8	20	II	3	0	0
8 to I2	24	9	I6	I0	2	0
4 to 8	I4	2	I2	22	6	I
0 to 4	2	I	8	22	46	47
0	I*	0	0	2	6	I2
Mean depth	I0.5	I6.I	I0.3	5.53	2.29	I.25

* QS deflection in VI

TABLE XXII

Depth of S wave in sixty healthy adults

Depth of S in mm.	Moderate counter-clockwise rotation (I9 cases)						Moderate clockwise rotation (29 cases)						Marked clockwise rotation (I2 cases)					
	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6
36 to 40	0	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0
32 to 36	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28 to 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24 to 28	I	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 to 24	0	I	0	0	0	0	0	2	2	0	0	0	0	I	I	0	0	0
I6 to 20	0	5	2	0	0	0	0	I0	5	I	0	0	0	5	3	0	0	0
I2 to I6	6	5	3	0	0	0	9	I3	6	3	0	0	3	2	2	0	0	0
8 to I2	5	3	3	I	0	0	I5	4	I0	4	I	0	4	2	3	5	I	0
4 to 8	6	I	5	6	I	0	3	0	4	I3	2	0	4	I	3	3	3	I
0 to 4	I	I	6	I0	I5	I3	2	0	2	8	23	24	0	0	0	4	8	I0
0	0	0	0	2	3	6	0	0	0	0	3	5	I*	0	0	0	0	I
Mean depth	I0.9	I6.5	7.94	3.07	I.I4	0.86	I0.4	I5.4	I2.I	6.55	2.43	I.I2	9.93	I7.I	I2.9	6.93	3.77	2.I7

* QS deflection in VI

The comparative distribution of the S waves in the three groups of cases is shown in Table XXII.

The range of amplitude of the S wave is approximately the same in each lead for the three groups. The distribution table however shows that in leads V3 to V6 the S wave tends to be smallest in the moderate counter-clockwise group and greatest in the marked clockwise group. Even taking into account the disparity in the numbers in the three groups it is evident that in leads V4 to V6 the S wave is most frequently absent in the moderate counter-clockwise group and least frequently absent in the marked clockwise group.

Relationship of height of R wave to depth of S wave (R/S ratio).

The relationship of the height of the R wave to the depth of the S wave is shown in Table XXIII.

TABLE XXIII

R/S ratio in sixty healthy adults

R/S ratio	VI	V2	V3	V4	V5	V6
R > S	I	3	I9	49	58	60
R = S	0	0	2	3	0	0
R < S	58*	57	39	8	2	0

* One case with a QS deflection in lead VI is not included.

The R/S ratios for the three groups of cases are shown separately in Tables XXIV, XXV and XXVI.

TABLE XXIV

R/S ratio in moderate counter-clockwise group (I9 cases)

R/S ratio	VI	V2	V3	V4	V5	V6
R > S	I	2	II	I9	I9	I9
R = S	0	0	I	0	0	0
R < S	I8	I7	7	0	0	0

TABLE XXV

R/S ratio in moderate clockwise group (29 cases)

R/S ratio	VI	V2	V3	V4	V5	V6
R > S	0	0	5	22	28	29
R = S	0	0	0	I	0	0
R < S	29	29	24	6	I	0

TABLE XXVI

R/S ratio in marked clockwise group (I2 cases)

R/S ratio	VI	V2	V3	V4	V5	V6
R > S	0	I	3	8	II	I2
R = S	0	0	I	2	0	0
R < S	II*	II	8	2	I	0

* One case with a QS deflection in lead VI is not included.

The change in the R/S ratio tends to occur in leads V2 and V3 in the moderate counter-clockwise group and in leads V4 and V5 in the moderate and marked clockwise groups.

Unusual patterns of the QRS complex.

An RSr' pattern occurs in lead VI in two cases of the moderate counter-clockwise group. An RSR' pattern occurs in lead VI in three cases of the moderate clockwise group. An RSR'S' pattern occurs in lead V4 in one case of the marked clockwise group.

T wave.

The results for the T waves are shown in distribution tables.

In Table XXVII the distribution in the sixty cases as a whole is shown. The T wave is inverted in lead VI in eleven cases; it is flat in lead VI in one case; it is diphasic in lead VI in seven cases. Five of these diphasic T waves have resultant positive values and two have resultant zero values.

The T wave is never inverted or flat in any other lead in the present series. In one case however it is slightly diphasic in leads V2 and V3 the resultant value being positive in each instance. The T wave tends to have its maximum value in leads V2 to V4.

TABLE XXVII

Amplitude of T wave in sixty healthy adults

Amplitude of T in mm.	VI	V2	V3	V4	V5	V6
I4 to I6	0	I	0	0	0	0
I2 to I4	0	3	2	I	0	0
IO to I2	0	9	9	2	0	0
8 to IO	0	IO	9	II	3	0
6 to 8	I	IO	I3	I5	5	2
4 to 6	4	I3	I5	I2	23	9
2 to 4	I7	IO	6	I2	22	29
0 to 2	24	4	6	7	7	20
0	3	0	0	0	0	0
-2 to 0	8	0	0	0	0	0
-4 to -2	3	0	0	0	0	0
Mean amplitude	I.48	6.97	6.70	5.80	4.27	2.87

The comparative distribution of the T waves in the three groups of cases is shown in Table XXVIII. The range of amplitude is approximately the same in each lead for the three groups. Some negative values occur for lead VI in each group. The only significant difference is in leads V5 and V6 where the amplitude of the T waves in the marked clockwise group is smaller than in the other two groups.

TABLE XXVIII

Amplitude of T wave in sixty healthy adults

Amplitude of T	Moderate counter-clockwise rotation (I9 cases)						Moderate clockwise rotation (29 cases)						Marked clockwise rotation (I2 cases)					
in mm.	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6	VI	V2	V3	V4	V5	V6
I4 to I6	0	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0
I2 to I4	0	2	I	I	0	0	0	I	I	0	0	0	0	0	0	0	0	0
I0 to I2	0	2	5	0	0	0	0	7	3	I	0	0	0	0	I	I	0	0
8 to I0	0	4	I	4	I	0	0	4	5	6	I	0	0	2	3	I	I	0
6 to 8	I	3	3	6	2	0	0	5	9	6	2	2	0	2	I	3	I	0
4 to 6	I	3	5	3	9	4	3	8	7	7	I3	3	0	2	3	2	I	2
2 to 4	5	4	2	3	4	I0	8	3	3	7	II	I5	4	3	I	2	7	4
0 to 2	6	I	2	2	3	5	I2	I	I	2	2	9	6	2	3	3	2	6
0	2	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0	0
-2 to 0	2	0	0	0	0	0	5	0	0	0	0	0	I	0	0	0	0	0
-4 to -2	2	0	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0
Mean amplitude	I.36	7.I	6.99	6.26	4.47	2.99	I.54	7.38	6.96	5.79	4.34	2.96	I.49	5.77	5.6	5.I	3.77	2.43

It would appear therefore that the amplitude of the T wave in precordial leads VI to V6 in healthy adults is not influenced to any great extent by normal variations in the amount of rotation around the longitudinal axis of the heart.

PART 111.

THE EFFECT OF RESPIRATION ON THE HUMAN ELECTROCARDIOGRAM.

PART 111.

The effect of Respiration on the Human Electrocardiogram.

SECTION 1.

Historical review.

The method of electrocardiography had not long been established when it was noted that respiratory movements could be associated with definite alterations in the cardiac action potentials as recorded by the limb leads. Thus, even before the string galvanometer had come into general use, Samojloff (1908) working with the capillary electrometer was able to show that the excursions of the mercury column varied rhythmically with deep respiration. He found that as a rule the amplitude of the waves in lead 1 became smaller during inspiration and larger during expiration, while in lead 11 the reverse changes occurred. These early observations were soon confirmed and extended by other investigators (Hoffmann, 1909; Kahn, 1909a and 1909b; Grau, 1909 and 1910). The cause of the changes remained in doubt, however, as Samojloff (1908) and Grau (1910) thought that they were due to alteration in the position of the heart, while Kahn (1909b)who had taken electrocardiograms of subjects while they performed the Valsalva experiment suggested that direct pressure effects on the heart during respiration might be at least partly responsible. A rational explanation of respiratory variations in the electrocardiogram was first given by Einthoven et al. (1913) in their classical paper in which the mathematical analysis of the galvanometric curves was described on the basis of the equilateral triangle theory. Actually the main principles had been outlined a little earlier by Einthoven (1912) himself, but the later article is fuller and merits a detailed review, not only because of its intrinsic value, but also because comparatively little has subsequently been added to the ideas expressed therein. By recording simultaneous electrocardiograms and pneumograms, Einthoven and his associates studied the effects of respiration in ten healthy men whose ages ranged from 19 to 65 years and found that striking changes occurred both in the form of the electrocardiogram and in the heart rate. The maxima and minima of heart rate did not necessarily coincide with the extremes of respiration and there was in fact considerable variation in the relationship of the heart rate to the pneumogram from individual to individual. This was attributed to the influence of vagal tone. Similar considerations applied to the changes noted in the P wave, which seemed to be related to the heart rate rather than to the phase of respiration. Since it was known that the form of the P wave was particularly susceptible to alteration by vagal effects (Ritchie, 1912), this finding was not unexpected. With regard to the ventricular electrocardiogram, however, the position was quite different, for here the maxima and minima of the waves coincided exactly with the extreme respiratory positions in every case. Where the main QRS deflection was directed upwards in both lead 1 and lead 111, the R wave became larger with expiration and smaller with inspiration in lead 1, while on the other hand it became smaller with expiration and larger with inspiration in lead 111; where the main QRS was directed upwards in lead 1 and downwards in lead 111, the amplitudes of the waves in both leads became larger on expiration and smaller on inspiration. Thus it was obvious that the algebraic alterations in the QRS remained consistent irrespective of its form. The direction of the T waves in leads 1 and 111 was affected in precisely the same manner as that of the QRS; but whereas in some cases QRS and T were altered in exact proportion to their sizes, in others the change in QRS was relatively much greater than that in T. The application of the equilateral triangle theory to these findings was demonstrated and it was shown mathematically (a) that the axis of the QRS in every case was rotated in a counter-clockwise direction during expiration, though the actual amount of rotation was different in each case, and (b) that the manifest size of R remained constant during this rotation. This latter fact was of extreme importance and was considered to be a practical illustration of the validity of the equilateral triangle schema. When similar calculations were applied to the T wave, it was found (a) that T rotated in the same direction as R on expiration, but that the amount of rotation was usually less and (b) that the manifest size of T did not remain constant but was increased during expiration. Since according to the theory an alteration in the manifest size of a wave could not be produced by a rotation of the heart around its antero-posterior axis, it was concluded that during respiration T must also be influenced by vagal tone. This was confirmed by further study of electrocardiograms of five of the subjects taken before and after exercise. In these it was found that there was a definite clockwise rotation of T and an increase in its manifest size after exercise, whereas there was no alteration in either the direction or manifest size of R. Measurements of the small and rather variable Q and S waves was difficult, but where calculations were feasible these waves too showed a counter-clockwise rotation during expiration. The same was true of the P wave in those cases where the effect of vagal tone could be discounted. It was finally concluded that the cause of all the rotations occurring in the same direction must be a rotation of the heart around its antero-posterior axis due to change in position of the diaphragm during respiration. This was in agreement with radiological observations (Groedel, 1912). Furthermore, it was also concluded that during respiration there could be little or no rotation of the heart around its longitudinal axis, because S showed only slight change during respiration but very marked change on turning from left side to right side, which was supposed to be accompanied by such a rotation. The lack of noteworthy changes in many individuals during normal breathing (Einthoven, 1908) was attributed to the fact that the heart was merely displaced upwards and downwards parallel to itself without any rotation, and such a displacement within ordinary limits would exert little or no influence on the electrocardiogram according to the equilateral triangle theory, whereas a slight rotation of the heart such as might be produced by deep breathing would cause considerable change.

About the same time Waller (1913a) was also studying the effects of respiration on the electrocardiogram. In one normal subject with a vertical heart, he found that R in lead 111 increased with inspiration and decreased with expiration; R in lead 1 showed the opposite changes; while R in lead 11 showed changes similar to but much less than those in lead 1. In another normal case with a transverse heart where lead 111 had a negative QRS deflection, the algebraic change was again the same i.e. lead 111 became less negative with inspiration and more negative with expiration; R in lead 1 behaved as in the first case, but R in lead 11 now changed in the same way as lead 111, though as before the changes were much less in degree. By calculation (Waller, 1913b), it was shown that in both cases there had been a considerable counter-clockwise rotation of the electrical axis of the heart with expiration. Soon afterwards Waller (1914a) demonstrated that, in suitable normal subjects, an ordinarily negative QRS in lead 111 could be rendered positive by extreme inspiration, while an ordinarily positive QRS in lead 111 could be rendered negative by extreme expiration. Finally by a mathematical treatment of the problem (Waller, 1914b), he was able to explain and clarify these apparently inconsistent results. His method differed considerably from that of Einthoven et al.(1913), but his conclusions were practically identical, for he too found that the electrical axis of the heart in the frontal plane underwent a counter-clockwise rotation during expiration and a clockwise rotation during inspiration. In addition, he showed that the inter-relationship of the leads is such that for the normal range of the electrical axis (angle α = 0° to 90°), lead 1 must always decrease with inspiration; lead 111 must increase with inspiration, though the increase is often algebraic; while lead 11 will increase with inspiration when α is small i.e. in the transverse type of heart, but will decrease with inspiration when α is more than 60° i.e. in the vertical heart.

A similar demonstration of the relationship of the three standard leads during rotation of the heart such as occurs in respiration was given by Lewis (1925b) on the basis of the equilateral triangle theory, though because of the different methods of calculation, the critical angles for some of the changes are slightly different. Lewis (1923) had also compared the rotation of the electrical and anatomical axes of the heart during respiration in a case in which a rifle bullet had been embedded in the heart. In the standing position, the amount of rotation of the two axes was exactly the same, but in the sitting position there was a wide divergence, the electrical axis being rotated very much more than the anatomical. It was noted however that in the sitting position, the left diaphragmatic dome moved more than the right, which was restricted compared with its movement in the standing position. Thus the bullet during expiration moved a little towards the midline whereas in the standing posture it had moved a little away from the midline, although its upward movement remained approximately the same in the two postures. Lewis suggested therefore that the apparent discrepancy in the sitting posture might be due to rotation around the long axis, but unfortunately this could not be confirmed radiologically owing to technical difficulties.

A somewhat similar case had been described (Bond et al., 1918) in which there apparently was rotation around the long axis with respiration, but electrocardiographic study had not been done in detail.

The effect of forced respiration on the standard lead electrocardiogram was studied by Herrmann and Wilson (1922). In a series of thirty normal cases, they found that deep inspiration usually converted curves in which lead 111 was of least amplitude, into curves in which lead 1 was of least amplitude; forced expiration on the other hand was only occasionally effective in converting curves of the latter type into curves of the former type. Again, forced expiration sometimes converted normal curves to curves which suggested left ventricular preponderance; but deep inspiration practically never converted a normal curve to one of right ventricular preponderance, because all the deflections in lead 1, including an S if present, were reduced in amplitude by inspiration, even though this did not seem to be in accord with the equilateral triangle theory. The explanation for this apparent discrepancy was thought to be a concomitant rotation of the heart about its long axis. In abnormal cases, respiration had little or no effect on curves of right preponderance; in fact, inspiration for some unknown reason often rendered the right preponderance less conspicuous. On the other hand, curves of left preponderance were frequently converted to normal by deep inspiration.

The effect of respiration on the electrocardiogram was also studied by Jones and Roberts (1929). In a series of normal individuals they found that in the standing position the electrical axis underwent a considerable counter-clockwise rotation between extreme inspiration and expiration. The amount varied, the average being 40°, and it was greater in men than in women. Respiratory rotation was also found to a lesser degree in the right and left lateral recumbent postures, being more marked in the former than the latter. Radiologically, they failed to obtain any constant correlation with possible rotation of an anatomical or geometrical axis of the heart. In contrast to their normal cases, a series of cases with fixation of the apex due to mediastino-pericardial adhesions showed practically no change in the electrocardiogram with respiration and this was considered to be a valuable diagnostic point. Some cases of true dextrocardia were also investigated and in them the respiratory movements were found to be of similar degree to the normal cases, but the rotation occurred in the opposite sense (i.e. the axis moved clockwise with expiration).

Changes in the form of the QRS as well as in its amplitude during different phases of respiration were emphasised by Woodruff (1933). These consisted in the appearance or disappearance of notching and slurring or in the alteration in position of such characteristics. They occurred most frequently in Lead III and could be independent of any change in amplitude, and were found in normal individuals as well as in patients with heart disease, particularly in the degenerative and arteriosclerotic group. As it was thought that they could not be explained entirely by alteration in the position of the heart due to diaphragmatic movement, the influence of vagal and sympathetic stimulation and of respiratory variation in the coronary blood flow were suggested as possible causal factors. Respiratory vagal effects on the P wave, PR interval and T wave had of course been demonstrated by many earlier observers (Ritchie, 1912, Einthoven et al., 1913, Wilson, 1915 and Jensen et al., 1932), but it had been uniformly accepted that QRS changes were due simply to rotation of the heart.

A further effect of respiration on the electrocardiogram was noted by Pardee (1930). In his description of the large Q wave in Lead III which was so often associated with left ventricular disease, he stated that it usually tended to disappear on deep inspiration. This was thought to be due to the heart becoming more vertical. These observations were confirmed by several subsequent investigators including Kossmann et al. (1936). The latter however made a more general study of the Q waves in all three standard leads and found that the response to respiration was rather variable.

The only systematic investigations of the possible effect of respiration on the unipolar extremity leads have also been associated with the elucidation of the deep Q in lead 111. Thus Lyle (1944) pointed out that a Q wave in lead 111 could be due to an R wave in lead VL, a Q wave in lead VF or a combination of both. She found that in most cases where the Q in 111 was due to an R in VL it could be abolished by inspiration due to decrease in the R in VL. This was not invariable however. On the other hand, if the Q in 111 was due partly or wholly to a Q in VF, it might be decreased with inspiration but never became less than the Q in VF. Repeating these observations in a larger series of cases with the augmented unipolar limb leads, Myers and Oren (1945) reached somewhat similar conclusions, though they also stressed that respiratory alterations in Q wave in lead aVF were of no great value in assessing its pathological significance.

As regards the precordial leads little or nothing is known concerning the effects of respiration. In a few normal cases Robinson et al.(1939) found that in lead 1VF inspiration caused a diminution in the R and T waves and could even cause inversion of the T wave. Somewhat similar changes have also been described in lead lVF by Master (1942).

From this survey it is obvious that though the effects of respiration on the standard leads have been studied intensively during the past, no comparable investigation has as yet been made on the unipolar limb and precordial leads. The observations to be described in this part of the thesis deal with the effects of respiration on the standard limb leads, unipolar limb leads and unipolar precordial leads, in a series of cases both normal and abnormal. One of the main objects was to determine whether the knowledge already gained from the standard leads could be correlated with the newer electrocardiographic theory of the unipolar lead patterns associated with varying positions of the heart.

SECTION 2.

Method and scope of investigation.

The general object of experiments described in this part of the thesis was to assess the effect of respiration on the electrocardiogram and to determine whether the electrocardiographic changes could be interpreted rationally by the unipolar method on the basis of rotation of the heart around its three axes.

Selection of Cases.

The total number of cases studied was forty of whom five were females.

As it was thought that the respiratory effects in health might differ from those in disease, it was decided to study two groups of subjects.

The first group comprised twenty healthy adults of whom two were females. The ages of the subjects ranged from 17 to 45 years. In the subsequent analysis and presentation of the results, this group is referred to as the normal group.

The second group comprised twenty subjects who were considered to be abnormal. The individual diagnoses are shown in the table on page 159. Two main factors were considered in choosing these cases. In the first place, on clinical grounds, the object was to obtain a representative selection of respiratory and cardiovascular or related syndromes. Secondly, an endeavour was made to

TABLE

DIAGNOSIS IN TWENTY ABNORMAL CASES STUDIED IN PART III

DIAGNOSIS		NUMBER OF CASES MALE	NUMBER OF CASES FEMALE	PLATE NUMBERS
CORONARY INSUFFICIENCY		I	0	II4 a,b
MYOCARDIAL INFARCTION	ANTERIOR	I	0	II5 a,b
	ANTERO-LATERAL	I	0	I26 a,b
	POSTERIOR	2	0	II6 a,b; I25 a,b
BUNDLE BRANCH BLOCK	RIGHT	I	0	I24 a,b
	LEFT (INCOMPLETE)	I	0	I29 a,b
MITRAL STENOSIS	CHRONIC ADHESIVE PERICARDITIS	I	0	II9 a,b
	AURICULAR FIBRILLATION CONGESTIVE HEART FAILURE	I	0	I28 a,b
HYPERTENSION	ESSENTIAL	0	2	II3 a,b; II8 a,b
	MALIGNANT	I	0	I23 a,b
CHRONIC BRONCHITIS		I	0	I30 a,b
CHRONIC BRONCHITIS with EMPHYSEMA		2	0	II2 a,b; II7 a,b
PNEUMOCONIOSIS		I	0	I27 a,b
THYROTOXICOSIS		0	I	I20 a,b
NEURO-CIRCULATORY ASTHENIA		I	0	III a,b
CHRONIC CHOLECYSTITIS		I	0	I2I a,b
IDIOPATHIC STEATORRHOEA		I	0	I22 a,b

include as many varieties as possible of abnormal QRS and T wave appearances in the standard limb leads. In the subsequent analysis and presentation of the results, this group is referred to as the abnormal group.

Method.

All the investigations were carried out with the subject in the dorsal recumbent posture and at least two hours after the previous meal. Multiple chest electrodes were used in conjunction with the electrode belt and switch box as already described in Part 1, Section 2. This arrangement not only facilitated the technical process of recording the various leads but also ensured that the chest electrodes maintained their same position relative to the chest wall during the different phases of respiration. Three recordings of each lead were made in succession. The first was taken during quiet respiration and was regarded as the control observation. The subject was then instructed to breathe in, breathe out, breathe in as deeply as possible and hold the breath in; a second tracing was then taken in full inspiration. After a few minutes of quiet breathing, he was instructed to breathe in, breathe out as far as possible and hold the breath out; a third tracing was then taken in full expiration. This process was repeated for each lead in turn.

In all cases, the following leads were recorded:-

(a) the three standard limb leads.

(b) the three unipolar limb leads.

(c) the six unipolar precordial leads V1 to V6.

In most of the cases, the unipolar limb leads were taken by the augmented Goldberger technique, but in six of the normal group the unaugmented method with additional exploring electrodes placed proximally on the limbs was employed. In one of the normal cases and in five of the abnormal cases additional extremity potentials using the unaugmented Wilson method were taken for comparison.

Arrangement and Description of Illustrative Plates.

The tracings from the twenty normal cases are shown in plates 91 to 110 and those from the twenty abnormal cases in plates 111 to 130. Each case has one plate number but the plates have two parts, (a) containing the standard limb and unipolar limb leads and (b) containing the unipolar precordial leads. In every instance, two representative complexes are shown so that any changes in the heart rate may be seen.

The standard limb leads, unipolar limb leads and unipolar precordial leads are dealt with separately. The appearances during quiet respiration are described first and are treated as control observations. The changes on full inspiration are then given, followed by the changes on full expiration.

In both the normal and abnormal groups, the individual cases are arranged according to the electro-cardiographic position of the heart in the control observation. Thus the vertical hearts are placed before the horizontal hearts and within these main divisions, the order is moderate counter-clockwise, moderate clockwise and marked clockwise depending on the amount of rotation around the longitudinal axis.

SECTION 3.

The Effect of Respiration on the Heart Rate.

In each case the heart rate was measured during quiet respiration, in full inspiration and in full expiration. During quiet respiration sinus arrhythmia was noted in twenty-four of the forty cases, and allowance was made for this by counting the rate over several representative complexes. With the breath held in full inspiration or in full expiration sinus arrhythmia did not occur.

Results.

Normal Cases.

During quiet respiration the heart rate in nineteen of the twenty cases in this group ranged from 53 to 88 beats per minute. The remaining case had a heart rate of 100 beats per minute.

With the breath held in full inspiration a significant decrease in the heart rate occurred in all of the nineteen cases in which the initial heart rate was 88 or less. In the remaining case in which the initial heart rate was 100 the rate remained unaltered. In the cases in which decrease occurred its amount bore no relationship to the initial heart rate and was independent of the presence or absence of sinus arrhythmia.

With the breath held in full expiration the heart rate showed little change from its initial value in quiet respiration. Thus in fifteen of the twenty cases the heart rate was unaltered. Of the remaining five cases three showed a slight decrease and two a slight increase in rate.

Abnormal Cases.

During quiet respiration the heart rate in the twenty cases in this group ranged from 40 to 94 beats per minute.

With the breath held in full inspiration a significant decrease in the heart rate occurred in eleven cases. In the remaining nine cases the heart rate was unaltered. As in the normal cases the amount of decrease bore no relationship to the initial heart rate, and was independent of the presence or absence of sinus arrhythmia. Among the cases showing no change was one of auricular fibrillation and one of sinus block due to digitalis.

With the breath held in full expiration the initial heart rate was unchanged in sixteen cases. Of the remaining four cases three showed a slight increase in rate and one a decrease.

Conclusions.

In normal subjects there appears to be a uniform tendency to slowing of the heart rate when the breath is held in full inspiration. The one exception in this series was a case in which the initial heart rate was 100 beats per minute and this remained unaltered.

In the series of abnormal cases, mainly suffering from cardiac and respiratory diseases, slowing of the heart rate is less frequent when the breath is held in full inspiration.

In both normal and abnormal cases the amount of decrease bears no relationship to the initial heart rate, and is independent of the presence or absence of sinus arrhythmia.

In normal and abnormal cases alike the heart rate shows little change when the breath is held in full expiration.

SECTION 4.

The Effect of Respiration on the Normal Electrocardiogram.

In this section the effects of respiration on the electrocardiogram in twenty normal cases are described. The control tracings were taken during quiet respiration and the changes ascribed to inspiration and expiration are those which occurred when the breath was held in full inspiration and in full expiration respectively.

The appearances in the standard limb leads, unipolar limb leads and precordial leads are described separately and an attempt is then made to correlate the changes in all three.

The complete sets of tracings from the twenty cases are shown in plates 91 to 110, with their accompanying descriptions. Each plate has two parts (a) containing the standard and unipolar limb leads, and (b) containing the unipolar precordial leads.

Standard Limb Leads.

The changes in the standard limb leads are described under the three headings, QRS axis, P wave and T wave.

QRS axis.

The control tracings show that nine cases have right axis deviation, five have left axis deviation and six have normal electrical axis.

On inspiration the electrical axis shows a shift to the right in all twenty cases though in five of them the shift is of relatively slight degree. In only one case is the shift sufficiently great to convert a frank left axis to a right axis deviation.

On expiration the electrical axis shows a shift to the left in ten cases but is unaltered in the remaining ten. In seven cases the shift is of relatively slight degree and in no case is it sufficiently great to convert a frank right axis to a left axis deviation.

P wave.

The control tracings show that seventeen cases have upright P waves in all three leads, two cases have diphasic P waves in lead 111 and one case has diphasic P waves in leads 11 and 111.

On inspiration the P wave remains unchanged in six cases. It is diminished in lead 1 alone in seven cases, in leads 1 and 111 in two cases, in leads 1 and 11 in one case and in leads 1, 11 and 111 in one case. It is diminished in lead 1 and increased in lead 111 in one case, diminished in lead 1 and increased in leads 11 and 111 in one case and increased in lead 111 alone in one case. The changes in the P wave on inspiration are therefore very variable and the only common tendency is a diminution of the P wave in lead 1 which occurs either alone or in combination with changes in the other leads in thirteen of the twenty cases.

On expiration no changes occur in the P wave in any of the cases.

T wave.

The control tracings show that eighteen cases have upright T waves in all three leads and two cases have upright T waves in leads 1 and 11 and diphasic T waves in lead 111.

On inspiration the changes in the T wave are frequent but variable. In only one case does the T wave remain unchanged in all leads but in the other nineteen cases the following nine varieties of change occur. It is diminished in all leads in seven cases, in leads 1 and 11 in two cases, in leads 1 and 111 in one case, in lead 1 alone in one case, and in lead 11 alone in one case. It is diminished in lead 1 and increased in lead 111 in two cases, diminished in leads 1 and 11 and increased in lead 111 in three cases and diminished in lead 1 and increased in leads 11 and 111 in one case. It is increased in lead 111 alone in one case. Considering the changes in each lead separately, in lead 1 the T wave is diminished in seventeen cases and unchanged in three cases; in lead 11 it is diminished in thirteen cases and increased in one case; in lead 111 it is diminished in eight cases and increased in eight cases. There seems therefore to be a general tendency for diminution of the T wave to occur in leads 1 and 11.

On expiration changes in the T wave are much less frequent. Thus in thirteen cases no change occurs in any of the leads. In four cases the T wave is increased in lead 1 and diminished in lead 111, in one case it is increased in lead 1 alone, in one case it is diminished in lead 111 alone and in one case it is diminished in leads 1 and 11. On expiration therefore there is a slight tendency for the T wave to be increased in lead 1 and diminished in lead111.

Unipolar Limb Leads.

The changes in the unipolar limb leads are described under the three headings, position of the heart, P wave and T wave.

Position of the Heart.

The heart is described as vertical when aVL has a QS or an rS or an rSr' pattern; aVF then has a qR or an RS pattern. The heart is considered to become more vertical if aVL shows an increase in QS or S or a decrease in r, and aVF shows a concomitant increase in R or decrease in S. If the reverse changes occur the heart is considered to become less vertical.

The heart is described as horizontal when aVL has a qR, qRs or QR pattern; aVF then has an rS, RS, Rs or qR pattern. The heart is considered to become more horizontal when aVL shows an increase in R and aVF shows a concomitant decrease in R or increase in S. If the reverse changes occur the heart is considered to become less horizontal.

Clockwise rotation around the long axis of the heart is considered to occur if aVR changes from an rS to a QR, Qr or qR pattern, and counter-clockwise rotation if the reverse change occurs.

Rotation of the apex of the heart around the transverse axis is described as forward when aVF has a qR pattern and as backward when aVF has an rS or RS pattern.

The control tracings show that in twelve cases the heart is vertical, in seven cases it is horizontal and in one case it is intermediate in position. This last case is so classified because both aVL and aVF have R patterns and the heart is therefore neither vertical nor horizontal. Of the twelve vertical hearts, nine show right axis deviation in the standard limb leads and three show no axis deviation. Of the seven horizontal hearts, five show left axis deviation and two show no axis deviation. The one intermediate heart shows no axis deviation.

On inspiration, with regard to rotation around the antero-posterior axis, nine of the vertical hearts become still more vertical and three show no significant change; one of the horizontal hearts becomes vertical, five become less horizontal and one shows no change; the intermediate heart tends to become vertical. With regard to rotation around the long axis, four vertical hearts and one horizontal heart show evidence of some clockwise rotation and in two of the vertical hearts this is the only change which occurs. With regard to rotation of the apex around the transverse axis, two of the horizontal hearts show minor changes which could be due to backward rotation of the apex; the remaining eighteen cases show no evidence of any rotation around this axis.

On expiration five of the vertical hearts become less vertical and seven show no significant change; six of the horizontal hearts become more horizontal and one shows no change; the intermediate heart shows no change. In none of the cases is there any evidence of rotation around the long or transverse axes.

P wave.

The control tracings show that in aVR the P wave is negative in all twenty cases. In aVL it is positive in twelve cases, negative in seven cases and flat in one case; the proportion of positive to negative is six to five in the vertical hearts and five to two in the horizontal hearts. In aVF it is positive in eighteen cases, flat in one case and diphasic in one case; the flat and diphasic P waves occur in vertical hearts.

On inspiration the changes are relatively slight. In fourteen cases no significant change occurs. In the remaining six cases the P wave becomes less negative in aVR and less positive or more negative in aVL. In aVF changes occur in only two cases the P wave becoming more positive in one and less positive in the other.

On expiration no significant changes occur in any case.

T wave.

The control tracings show that in aVR the T wave is negative in all twenty cases. In aVL it is positive in thirteen cases, flat in two cases, negative in four cases and diphasic in one case; in the vertical hearts it is positive in seven cases, negative in four cases and diphasic in one case, while in the horizontal hearts it is positive in five cases and flat in two cases. In aVF the T wave is positive in all twenty cases.

On inspiration changes occur in two or more of the unipolar limb leads in fourteen cases which include seven vertical, six horizontal and one intermediate. In aVR the T wave becomes less negative in all fourteen cases. In aVL the T wave becomes less positive when its original value is positive and more negative when its original value is negative in the fourteen cases. This is particularly obvious in the horizontal group where the T wave from being upright or flat becomes flat or inverted respectively. In aVF the changes are more variable, the T wave becoming more positive in six cases, less positive in six cases and showing no change in two cases.

On expiration significant changes occur in only six cases, comprising five horizontal and one vertical. In aVR the T wave becomes more negative in three cases and shows no change in three cases. In aVL the T wave becomes more positive in six cases. In aVF the T wave becomes less positive in five cases and is unchanged in one case, this last being one of the horizontal group.

Precordial Leads.

The changes in the precordial leads are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The precordial leads are used to decide the amount of rotation around the long axis of the heart. The determining characteristic is the first appearance of an initial q in the ventricular pattern. The complete pattern may be either qRs or qR. The heart is described as having marked counter-clockwise rotation if q first appears in V2, moderate counter-clockwise rotation if q appears first in V3 or V4, moderate clockwise rotation if q first appears in V5 or V6 and marked clockwise rotation if q fails to appear in any of the precordial leads. The following changes are considered to be evidence of further clockwise rotation:-

Shift of q one or more places to the left.

Reduction in amplitude of q.

Reduction in amplitude of R or r.

Increase in amplitude of S or s.

Appearance of s in qR or R patterns.

Change of pattern from RS to rS.

Change of pattern from Rs to RS.

The control tracings show that of the vertical hearts four have moderate counter-clockwise rotation, six have moderate clockwise rotation and two have marked clockwise rotation. Of the horizontal hearts two have moderate counter-clockwise rotation, three have moderate clockwise rotation and two have marked clockwise rotation. The intermediate heart shows marked clockwise rotation.

On inspiration eighteen of the twenty cases show evidence of clockwise rotation; the remaining two show no change. The eighteen cases include eleven vertical hearts and seven horizontal hearts. The two cases showing no change are one vertical heart with moderate counter-clockwise rotation and the intermediate heart with marked clockwise rotation. A shift of the q wave occurs in seven cases, five vertical hearts and two horizontal hearts. It should be noted that as five of the twenty cases show marked clockwise rotation in the control tracings, shift of the q wave is possible only in the remaining fifteen cases. Four of the vertical hearts have moderate clockwise rotation and two of these are converted to marked clockwise rotation. The remaining vertical heart has moderate counter-clockwise rotation and this is converted to moderate clockwise rotation. One of the horizontal hearts has moderate counter-clockwise rotation and this is converted to moderate clockwise rotation. The other has moderate clockwise rotation with the q first appearing in V5 and this is still classed as moderate clockwise rotation but with the q now appearing first in V6.

On expiration the changes are less obvious and less frequent. Eleven cases show evidence of some counter-clockwise rotation. These include five vertical, five horizontal and one intermediate heart. The other nine cases show no change. Shift of the q wave does not occur in any case.

P wave.

No significant changes occur in the P wave with either inspiration or expiration.

T wave.

In the cases showing changes in the QRS complexes with respiration, minor changes are present in the T waves in keeping with the clockwise or counter-clockwise rotation which occurs. On inspiration however several cases show more reduction in the amplitude of the T waves in V4 to V6 than might be expected. This might be due to a recession or backward displacement of the apex from the anterior chest wall on inspiration.

Correlation of the Changes in the Standard Limb, Unipolar Limb and Precordial Leads.

From the detailed results presented in this section it is evident that on full inspiration consistent changes occur in the three types of lead in every case. On full expiration the changes are less frequent but again they are consistent and are the reverse of those which occur on full inspiration. As regards the standard limb leads the findings are in agreement with those of previous observers. With the aid of the unipolar limb and precordial leads however it is now possible to obtain a rational explanation of these changes.

Inspiration.

The standard limb leads in every case show a shift of the QRS axis to the right.

The unipolar limb leads show that in sixteen cases the heart becomes more vertical or less horizontal or even changes from horizontal to vertical; in three of these cases there is also evidence of some clockwise rotation. In two cases there is evidence of clockwise rotation alone. The remaining two cases show no change in the unipolar limb leads but there is evidence of clockwise rotation in the precordial leads.

The precordial leads show evidence of clockwise rotation in eighteen cases. The remaining two cases show no change in the precordial leads but the unipolar limb leads show that the heart has become more vertical in each case.

In two cases the unipolar limb leads show evidence of backward rotation of the apex around the transverse axis.

With inspiration therefore the heart usually undergoes clockwise rotation around both its antero-posterior and longitudinal axes. Occasionally clockwise rotation around one or other of these axes occurs alone. There is little or no tendency to rotation around the transverse axis but when it does occur it takes the form of backward rotation of the apex, presumably in association with the clockwise rotation around the longitudinal axis. The effect of the combined rotation is evident in the standard limb leads in all cases, where it produces a shift of the QRS axis to the right.

Expiration. -

The standard limb leads show a shift of the QRS axis to the left in ten cases and no change in the remaining ten.

The unipolar limb leads show that in eleven cases the heart becomes less vertical or more horizontal, while in nine cases there is no change.

The precordial leads show evidence of counter-clockwise rotation in eleven cases and no change in the other nine.

Changes in both unipolar limb and precordial leads are present in six cases; changes in unipolar limb leads alone are present in five cases; changes in the precordial leads alone are present in five cases. Of the twenty cases therefore sixteen show evidence of change in the unipolar limb leads or the precordial leads or both, while four cases show no change in either the unipolar limb or precordial leads.

The sixteen cases showing evidence of change in the unipolar leads include nine cases which show a shift of the QRS axis to the left in the standard limb leads and seven cases which show no change in the standard limb leads. The four cases showing no evidence of change in the unipolar leads include three cases which show no change in the standard limb leads and one case which shows a slight shift of the QRS axis to the left in the standard limb leads. No explanation can be given for this one exception although it could possibly be due to a minor error in standardisation.

With expiration therefore the heart may undergo some degree of counter-clockwise rotation around both its antero-posterior and longitudinal axes. Frequently however counter-clockwise rotation around one or other of these axes occurs alone. There is no evidence of any rotation of the heart around its transverse axis. The effect of the combined rotation is evident in the standard limb leads in just over half of the cases where it produces a shift of the QRS axis to the left. In the remaining cases the amount of rotation appears to be insufficient to produce any obvious changes in the standard limb leads.

SECTION 5.

The Effect of Respiration on the Abnormal Electrocardiogram.

In this section the effects of respiration on the electrocardiogram in twenty abnormal cases are described. The control tracings were taken during quiet respiration and the changes ascribed to inspiration and to expiration are those which occurred when the breath was held in full inspiration and in full expiration respectively.

The appearances in the standard limb leads, unipolar limb leads and precordial leads are described separately, and an attempt is then made to correlate the changes in all three.

The complete sets of tracings from the twenty cases are shown in plates 111 to 130, with their accompanying descriptions. Each plate has two parts, (a) containing the standard and unipolar limb leads, and (b) containing the unipolar precordial leads.

Standard Limb Leads.

The changes in the standard limb leads are described under the three headings, QRS axis, P wave and T wave.

QRS axis.

The control tracings show that five cases have right axis deviation, four have left axis deviation and eleven have no axis deviation.

On inspiration the electrical axis shows a shift to the right in all twenty cases though in three of them the shift is of relatively slight degree. In no case is the shift sufficiently great to convert a frank left axis to a right axis deviation.

On expiration the electrical axis shows a shift to the left in thirteen cases though in two of them the shift is of relatively slight degree. In no case is the shift sufficiently great to convert a frank right axis to a left axis deviation. The remaining seven cases show no shift in the electrical axis.

P wave.

The control tracings show that sixteen cases have upright P waves in all three leads, two cases have diphasic P waves in lead 111 and one case has a flat P wave in lead 1. The remaining case is one of auricular fibrillation.

On inspiration the P wave remains unchanged in nine cases. In the remaining ten cases it shows changes in two or three leads. Thus it is diminished in lead 1 and increased in leads 11 and 111 in three cases, diminished in lead 1 and increased in lead 111 in three cases, diminished in leads 1 and 11 in one case, diminished in leads 1 and 111 in one case, diminished in leads 11 and 111 in one case and increased in leads 11 and 111 in one case. The changes in the P wave on inspiration are therefore somewhat variable though there is a common tendency for diminution to occur in lead 1.

On expiration no significant changes occur in the P wave in any of the cases.

T wave.

The control tracings show that ten cases have upright T waves in all three leads, one case has upright T waves in leads 1 and 11 and a diphasic T wave in lead 111, two cases have upright T waves in leads 1 and 11 and an inverted T wave in lead 111, four cases have upright T waves in lead 1, diphasic T waves in lead 11 and inverted T waves in lead 111, and one case has an upright T wave in lead 1 and inverted T waves in leads 11 and 111. One case has an inverted T wave in lead 1 and upright T waves in leads 11 and 111, and one case has an inverted T wave in lead 1, diphasic T wave in lead 11 and upright T wave in lead 111.

On inspiration changes occur in the T waves in fifteen cases. Considering changes in amplitude alone it is found that the T wave is diminished in all three leads in six cases, it is diminished in leads 11 and 111 in two cases and is diminished in leads 1 and 11 in one case. It is diminished in lead 1 and increased in lead 111 in two cases, it is diminished in leads 1 and 11 and increased in lead 111 in two cases, it is diminished in lead 1 and increased in leads 11 and 111 in one case, and diminished in leads 1 and 111 and increased in lead 11 in one case. When the original direction of the T wave is taken into account it is found that in lead 1 out of a total of thirteen changes the T wave becomes less positive in twelve cases and less negative in one case; in lead 11 out of a total of thirteen changes the T wave becomes less positive in ten cases, more positive in two cases and less negative in one case; in lead 111 out of a total of fourteen changes the T wave becomes less positive in five cases, more positive in three cases, less negative in four cases and more negative in two cases. There is therefore a uniform tendency for reduction in the amplitude of the T wave to occur in lead 1 whether it be originally upright or inverted. In lead 111 however either increase or reduction in amplitude can occur with both upright and inverted T waves. The changes in lead 11 are in general similar to those in lead 1 but are liable to be affected by the type of change in lead 111.

On expiration changes in the T wave are less frequent. Thus in twelve cases no change occurs in any of the leads. In one case the T wave is increased in amplitude in all three leads, in two cases it is increased in lead 1 and diminished in lead 111, and in one case it is increased in leads 1 and 111 and diminished in lead 11. In one case it is diminished in lead 1 and increased in lead 11, in one case it is diminished in lead 1 and increased in lead 111, in one case it is diminished in lead 11 and increased in lead 111, and in one case it is diminished in leads 11 and 111. When the original direction of the T wave is taken into account it is found that in lead 1 out of a total of six changes the T wave becomes more positive in three cases, less positive in two cases and more negative in one case; in lead 11 out of a total of five changes it becomes more positive in one case, less positive in two cases, more negative in one case and less negative in one case; in lead 111 out of a total of seven changes it becomes more positive in three cases, less positive in two cases, more negative in one case and less negative in one case. There is therefore no tendency for a constant change to occur in any of the leads.

Unipolar Limb Leads.

The changes in the unipolar limb leads are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The criteria for determining the position of the heart are the same as those employed in Section 4.

The control tracings show that in twelve cases the heart is vertical and in eight cases it is horizontal. Of the twelve vertical hearts, four show right axis deviation in the standard limb leads, one shows left axis deviation and seven show no axis deviation. Of the eight horizontal hearts, three show left axis deviation, one shows right axis deviation and four show no axis deviation.

On inspiration with regard to rotation around the antero-posterior axis, ten of the vertical hearts become still more vertical and two show no significant change; two of the horizontal hearts become vertical, five become less horizontal and one shows no change. Thus seventeen of the twenty hearts show evidence of rotation around the antero-posterior axis of varying degree but in the same sense in all cases, while three show no change. With regard to rotation around the long axis, one of the horizontal hearts shows evidence of some clockwise rotation as its only change in position. The remaining nineteen hearts show no evidence of rotation around this axis. With regard to rotation of the apex around the transverse axis, two of the vertical hearts and one of the horizontal hearts show minor changes which could be due to backward rotation of the apex; the remaining seventeen cases show no evidence of any rotation around this axis.

On expiration with regard to rotation around the antero-posterior axis, eight of the vertical hearts become less vertical and four show no significant change; five of the horizontal hearts become still more horizontal and three show no change. Thus thirteen of the twenty hearts show evidence of rotation around the antero-posterior axis of varying degree but in the same sense in all cases, while seven show no change. With regard to rotation around the long axis, one of the horizontal hearts shows evidence of some counter-clockwise rotation as its only change in position. The remaining nineteen hearts show no evidence of rotation around this axis. With regard to rotation of the apex around the transverse axis, one of the vertical and one of the horizontal hearts show evidence of forward rotation of the apex. The remaining eighteen hearts show no evidence of rotation around this axis.

P wave.

The control tracings show that in aVR the P wave is negative in all nineteen cases. In aVL it is positive in five cases, negative in eight cases, flat in five cases and diphasic in one case; the proportion of positive to negative is three to five in the vertical hearts and two to three in the horizontal hearts. In aVF it is positive in eighteen cases and diphasic in one case.

On inspiration no significant changes occur in twelve cases. In the remaining seven cases, four of which are vertical and three horizontal hearts, significant but rather variable changes occur. Thus in two cases the P wave becomes less negative in aVR and less positive in aVL, in two cases it becomes less negative in aVR and more negative in aVL, in one case it becomes more negative in aVL and more positive in aVF, in one case it becomes more negative in aVR and more positive in aVF, and in one case it becomes less negative in aVR and more positive in aVL and aVF. Considering the changes in each lead separately, in aVR out of a total of six changes, the P wave becomes less negative in five cases, four of which are vertical and one horizontal; it becomes more negative in one case which is horizontal. In aVL out of a total of six changes, it becomes less positive in two cases one of which is vertical and the other horizontal; it becomes more negative in three cases, two of which are vertical and one horizontal; it becomes more positive in one case which is vertical. In aVF it becomes more positive in three cases, one of which is vertical and two horizontal. There is therefore some tendency for the P wave to become less negative in aVR, less positive or more negative in aVL and more positive in aVF irrespective of whether the heart is vertical or horizontal.

On expiration no significant change occurs in any case.

<u>T wave</u>.

The control tracings show that in aVR the T wave is negative in eighteen cases, positive in one case and diphasic in one case. In aVL it is negative in nine cases, positive in eight cases, flat in two cases and diphasic in one case; in the vertical hearts it is positive in six cases, negative in four cases and flat in two cases, while in the horizontal hearts it is positive in two cases, negative in five cases and diphasic in one case. In aVF the T wave is positive in twelve cases, negative in four cases and diphasic in four cases; in the vertical hearts it is positive in seven cases, negative in three cases and diphasic in two cases, while in the horizontal hearts it is positive in five cases, negative in one case and diphasic in two cases.

On inspiration, changes occur in the T waves in twelve cases of which six are vertical and six horizontal. Considering changes in amplitude alone it is found that a large number of possible combinations can occur. Thus the T wave is diminished in all leads in two cases, one vertical and one horizontal; it is diminished in aVR and aVF in two cases, one horizontal and one vertical; it is diminished in aVR and increased in aVL in one vertical case; it is diminished in aVR and aVF and increased in aVL in one horizontal case;

it is diminished in aVR and aVL and increased in aVF in one vertical case; it is diminished in aVR and increased in aVL and aVF in one vertical case; it is increased in aVR and diminished in aVL in one horizontal case; it is increased in aVR and aVF and diminished in aVL in one horizontal case; it is diminished in aVL and aVF in one horizontal case; it is increased in aVL and aVF in one vertical case. When the original direction of the T wave is taken into account it is found that in aVR, out of a total of ten changes, the T wave becomes less negative in eight cases of which five are vertical and three horizontal; it becomes more positive in one horizontal case; it becomes more negative in one horizontal case. In aVL out of a total of ten changes, the T wave becomes less positive in four cases of which two are vertical and two horizontal; it becomes more negative in four cases of which three are vertical and one horizontal; it becomes less negative in two horizontal cases. In aVF, out of a total of ten changes, the T wave becomes less positive in four cases of which one is vertical and three are horizontal; it becomes more negative in two cases of which one is vertical and one horizontal; it becomes more positive in two vertical cases; it becomes less negative in two cases of which one is vertical and one horizontal. Irrespective of whether the heart is vertical or horizontal therefore, there seems to be a tendency for the T wave in aVR to become less negative or more positive and for the T wave in aVL to become more negative or less positive. In aVF however there is no uniform trend and irrespective of whether the heart is vertical or horizontal the T wave may become on the one hand more positive or less negative, or on the other hand it may become less positive or more negative.

On expiration changes occur in the T wave in nine cases of which five are vertical and four horizontal. Considering changes in amplitude alone it is found again that a large number of possible combinations can occur. Thus the T wave is increased in all leads in two cases, one vertical and one horizontal; it is increased in aVR and diminished in aVL in two cases, one vertical and one horizontal; it is increased in aVR and diminished in aVF in one vertical case; it is diminished in aVR and aVF in one horizontal case; it is increased in aVL and aVF in one horizontal case; it is diminished in aVL and aVF in one vertical case; it is increased in aVL and diminished in aVF in one vertical case. When the original direction of the T wave is taken into account it is found that in aVR, out of a total of six changes, the T wave becomes more negative in five cases of which three are vertical and two horizontal; it becomes less negative in one horizontal case. In aVL, out of a total of seven changes, the T wave becomes more positive in two cases, one vertical and one horizontal; it becomes less negative in two cases, one vertical and one horizontal; it becomes less positive in one vertical case; it becomes more negative in two cases, one vertical and one horizontal. In aVF, out of a total of seven changes, it becomes more positive in two cases, one vertical and one horizontal; it becomes less negative in two vertical cases; it becomes less positive in two cases, one vertical and one horizontal; it becomes more negative in one horizontal case. The trend of the T wave changes in aVR and aVL is therefore the reverse of that on inspiration and again there is the same lack of uniformity with respect to the T wave changes in aVF.

Precordial Leads.

The changes in the precordial leads are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The criteria for determining the amount of rotation of the heart around its long axis are the same as those employed in Section 4.

The control tracings show that of the twelve vertical hearts, one has moderate counter-clockwise rotation, two have moderate clockwise rotation and nine have marked clockwise rotation. Of the eight horizontal hearts, two have moderate counter-clockwise rotation, four have moderate clockwise rotation and two have marked clockwise rotation.

On inspiration nineteen of the twenty cases show evidence of clockwise rotation. The remaining case, a vertical heart with marked clockwise rotation, shows no change. A shift of the q wave occurs in four cases. It should be noted that as eleven of the cases show marked clockwise rotation in the control tracings shift of the q is possible only in the remaining nine cases. The four cases showing shift of the q wave include two vertical and two horizontal hearts. One of the vertical hearts has moderate clockwise rotation and this is converted to marked clockwise rotation; the other has moderate counter-clockwise rotation and this is converted to moderate clockwise rotation. One of the horizontal hearts has moderate clockwise rotation and this is converted to marked clockwise rotation; the other has moderate counter-clockwise rotation and this is converted to moderate clockwise rotation.

On expiration the changes are less frequent. Ten cases show evidence of some counter-clockwise rotation. These include six vertical and four horizontal hearts. Shift of the q wave to the right occurs in one case. This is a vertical heart with moderate clockwise rotation which is converted to moderate counter-clockwise rotation. The remaining eleven cases show no change.

P wave.

No significant changes occur in the P wave with either inspiration or expiration.

T wave.

In the cases showing changes in the QRS complexes with respiration, minor changes in the amplitude of the T waves also occur in keeping with the clockwise or counter-clockwise rotation produced. Otherwise there are no significant alterations.

Correlation of the Changes in the Standard Limb, Unipolar Limb and Precordial Leads.

From the detailed results presented in this section it is evident that on full inspiration consistent changes occur in the three types of lead in all cases. On full expiration the changes are less frequent but again they are consistent and are the reverse of those which occur on full inspiration. As regards the standard leads the findings are in general agreement with those of previous observers. With the aid of the unipolar limb and precordial leads, however, it is now possible to offer a rational explanation of these changes particularly with respect to the QRS complex.

Inspiration.

The standard limb leads in every case show a shift of the QRS axis to the right.

The unipolar limb leads show that in seventeen cases the heart becomes more vertical or less horizontal or changes from horizontal to vertical. In one case there is evidence of clockwise rotation alone. The remaining two cases show no change in the unipolar limb leads but there is evidence of clockwise rotation in the precordial leads.

The precordial leads show evidence of clockwise rotation in nineteen cases. The remaining case shows no change in the precordial leads but the unipolar limb leads show that the heart becomes more vertical.

In three cases the unipolar limb leads show evidence of backward rotation of the apex around the transverse axis.

With full inspiration therefore the abnormal heart usually undergoes clockwise rotation around both its antero-posterior and longitudinal axes. Occasionally clockwise rotation around one or other of these axes occurs alone. There is little or no tendency to rotation around the transverse axis but when this does occur it takes the form of backward rotation of the apex in association with clockwise rotation around the longitudinal axis. The effect of the combined clockwise rotation around the antero-posterior and longitudinal axes is evident in the standard limb leads in all cases, where it produces a shift of the QRS axis to the right.

Expiration.

The standard limb leads show a shift of the QRS axis to the left in thirteen cases and no change in the remaining seven cases.

The unipolar limb leads show that in thirteen cases the heart becomes less vertical or more horizontal and in two of these cases there is also evidence of forward rotation of the apex; in one case counter-clockwise rotation occurs as the only change. In the remaining six cases the unipolar limb leads are unaltered.

The precordial leads show evidence of counter-clockwise rotation in ten cases and no change in the remaining ten cases.

Changes in both unipolar limb and precordial leads are present in six cases; changes in the unipolar limb leads alone are present in eight cases; changes in the precordial leads alone are present in four cases. Of the twenty cases therefore eighteen show evidence of changes in the unipolar limb leads or the precordial leads or both, while two cases show no changes in either the unipolar limb leads or precordial leads.

The eighteen cases showing evidence of changes in the unipolar leads include thirteen cases which show a shift of the QRS axis to the left in the standard limb leads and five cases which show no changes in the standard limb leads. The two cases showing no evidence of changes in the unipolar leads show no changes in the standard limb leads.

With full expiration therefore the abnormal heart may undergo some degree of counter-clockwise rotation around both its antero-posterior and longitudinal axes. Frequently, however, counter-clockwise rotation around one or other of these axes occurs alone. There is little or no tendency to rotation around the transverse axis but when it does occur it takes the form of forward rotation of the apex. The effect of the combined counter-clockwise rotation around the antero-posterior and longitudinal axes is evident in the standard limb leads in approximately two-thirds of the cases, where it produces a shift of the QRS axis to the left. In the remaining one third the amount of rotation appears to be insufficient to produce any obvious changes in the standard limb leads.

STUDIES IN ELECTROCARDIOGRAPHY

VOLUME II

PARTS IV AND V

and

REFERENCES

PART 1V.

THE EFFECT OF POSTURE ON THE HUMAN ELECTROCARDIOGRAM.

"Die herzlage beeinflusst die Form des E.K.G.. Es ist uns jedoch bei der elektrokardiographischen Untersuchung hauptsächlich darum zu tun, die Tätigkeit des Herzens besser zu ermitteln, und man sieht leicht ein, dass wenn schon durch eine Lageabweichung dieses Organs eine Veränderung in die Form der Kurve hervorgerufen wird, eine Schwierigkeit entstehen muss, um mittels dieser Form auch über die Tätigkeit des Herzens zu urteilen.

Diese Schwierigkeit kann am besten gelöst werden, wenn man den Einfluss der Lage vorher genau kennen gelernt hat."

"The position of the heart influences the form of the E.C.G.. Our main purpose in electrocardiography, however, is to acquire a better understanding of the activity of the heart and it is obvious that if an alteration in the form of the curve has been produced by a mere change in the position of the organ, then difficulty must arise in forming any opinion on cardiac activity from the appearance of this tracing. This difficulty can best be overcome if one has previously learned to recognise accurately the influence of position."

<u>Einthoven et al., 1913.</u>

PART 1V.

The effect of Posture on the Human Electrocardiogram.

SECTION 1.

Historical review.

It is a fundamental principle in electrocardiography that the form of the tracing depends firstly on the size and direction of the cardiac action potentials, and secondly on the position of the recording electrodes in relation to the heart. If certain fixed leads are chosen, then it is only to be expected that an alteration in the position of the heart will produce changes in the form of the curves obtained from these several leads. This was first demonstrated clinically by Waller (1889) in one of his early papers on the electrocardiogram. Using a variety of leads, including those subsequently termed Leads 1, 11 and 111, he compared the tracings obtained from a normal individual with those from two subjects with situs viscerum inversus. As he anticipated, differences of varying degree were present in many of the leads; but in Lead 1, and only in that lead, the direction of all the deflections in the dextrocardiac patients was exactly opposite to that in the normal. He explained this correctly by pointing out that in dextrocardia the electrode points for Lead 1 were simply reversed with respect to the heart, while this of course did not apply to the other leads. These observations were amply confirmed later by Einthoven et al.(1913) and Lewis (1925a). Apart from the obvious example of transposition of the heart, it was soon recognised that even relatively slight changes in its position, such as might be produced by alterations in posture, could have significant effects on the electrocardiogram. Thus Einthoven and Lint (1900), still working with the capillary electrometer, found in three normal subjects that turning from the right side to the left side caused the S wave in Lead 1 to become much larger, while P, Q, R and T all tended to become slightly smaller. Postural changes were also noted by Grau (1909, 1910) and by Hoffmann (1909).

With the introduction of the string galvanometer (Einthoven, 1903), more exact observations were made possible, and a systematic investigation by Einthoven et al. (1913) of the influence on the electrocardiogram of change in position of the body soon followed. They studied ten normal individuals and found that in five cases the S wave in Lead 1 became greater on turning from the left side to the right side; in three others it was absent in both postures; in the remaining two, an S wave was present in Lead 1 but remained unaltered. The change was considered to be due to a rotation of the heart around its long axis, though in which direction was not explicitly stated, and it was further concluded that the S wave in Lead 1 was due to a cardiac potential acting in the sagittal direction, i.e. at right angles to the frontal plane. The P, R and T waves remained practically unchanged and it was therefore concluded that they were produced by potential changes occurring in approximately the frontal plane. Furthermore since this postural change was thought of necessity to be accompanied by some degree of lateral shift of the heart, the lack of obvious change in the P, R and T waves was accepted as confirmation of their view that within limits a total displacement of the heart parallel to itself had practically no effect on the standard lead electrocardiogram.

A change from the supine to the prone posture caused a counter-clockwise rotation of the heart around its antero-posterior axis, similar to that in expiration, in all ten cases. This was attributed to increased abdominal pressure in the prone posture with consequent upward displacement of the diaphragm. There was also evidence in some cases of a slight rotation around the long axis, as shown by alteration in the S wave.

The differences between the sitting and the supine postures in all ten cases were relatively slight. In some, there was evidence of counter-clockwise rotation around the antero-posterior axis in the sitting posture (as in expiration) and of a clockwise rotation in the recumbent posture (as in inspiration); in others however, there was no significant change.

Waller (1913c) also studied mathematically the effect of various postures on the electrocardiogram and found that the most obvious alteration occurred when lying on the left side. In this posture, according to him, the electrical axis became much more vertical, whereas in the right lateral posture it tended to become more horizontal though the change was relatively much less. He also noted the effect of respiration in various postures and stated that in general the electrical axis became more horizontal with expiration; this change was most marked in the upright posture and was progressively less in the sitting, dorsal recumbent, right lateral and left lateral postures. The effect in the left lateral posture was practically negligible. Later observers, however, have failed to confirm these findings (Dieuaide, 1925, Jones and Roberts, 1929).

All the observations so far described have been concerned with an actual or presumed alteration in the position of the heart with respect to certain fixed leads from the body. The reverse procedure however is also feasible, whereby a suitable system of leads may be rotated around the heart as a fixed point; thus, for example, a certain measured clockwise rotation of the leads around the antero-posterior axis of the heart would produce the same effect as an equivalent counter-clockwise rotation of the heart round this axis. Using this principle, Herrmann and Wilson (1922) demonstrated in a very simple manner the theoretical effect on the three standard leads of rotation of the heart about its antero-posterior axis in successive stages of 60°. The effect of a counter-clockwise rotation of the heart through 60° (or a clockwise rotation through 300°) is given by substituting Lead 11 for Lead 1, Lead 111 for Lead 11 and -Lead 1 for Lead 111. Similar substitutions can be worked out for 120°, 180°, 240° and 300° rotations as shown in fig. I6 . These calculations of course depend on the validity of the equilateral triangle hypothesis. When normal electrocardiograms were considered in this way, it was found that counter-clockwise rotation of the heart appeared to produce a QRS pattern of left, and clockwise rotation one of right, ventricular preponderance. They summarised the differences between the effects of preponderance and the effects of rotation as follows:-

(1) Rotation produces changes in the P and T waves similar to those in the QRS complex; preponderance does not affect the P wave and it affects the T wave differently.

(2) Preponderance can produce changes in the QRS complex which demand a much greater degree of rotation than is conceivable in the body under ordinary conditions; this had previously been stressed by Einthoven et al.(1913) and Lewis (1914).

(3) Rotation of the heart cannot materially increase the amplitude of the tallest deflection of the three leads, because it cannot increase the manifest potential (Einthoven et al., 1913) and the tallest deflection

represents at least 85 per cent (cos 30°) of this; preponderance on the other hand is often associated with very large deflections in one or more leads.

(4) In normal curves, with rotation, corresponding peaks remain in phase; in preponderance curves, corresponding peaks are seldom in phase.

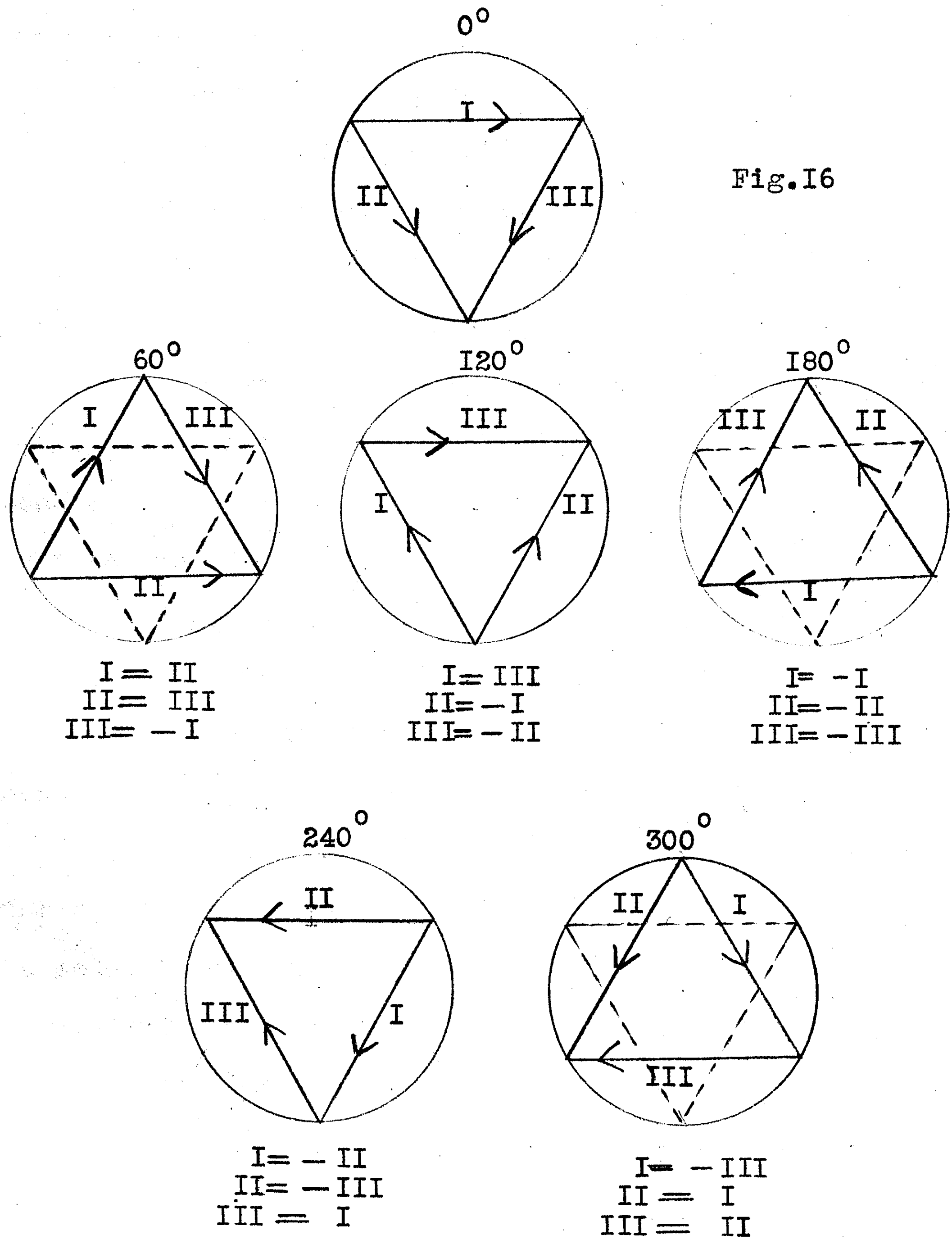


Fig.I6

From a consideration of these facts and from their correlation of autopsy findings with electrocardiograms, Herrmann and Wilson (1922) finally concluded that the form of the normal electrocardiogram was determined not by the relative weights of the two ventricles but by (a) the position of the heart and (b) the arrangement of the ventricular conducting system.

A practical attempt to simulate rotation of the heart around its antero-posterior axis was made by Cohn and Raisbeck (1922a). In two normal individuals they constructed the largest equilateral triangle which could be laid on the chest with its centre over the mid-sternum approximately at the level of the third rib, and its apices at the shoulders and the epigastrium. Curves taken in the usual manner from these points closely resembled the three standard limb leads and satisfied the equation Lead 11 = Lead 1 + Lead 111. The triangle was then rotated around its centre in stages of 40° and equivalent curves were recorded from the apices in each successive position. From the results obtained it was concluded that moderate counter-clockwise rotation of the heart produced QRS curves of left preponderance, while moderate clockwise rotation produced curves of right preponderance; the P and T waves however pointed in the same direction as the QRS complexes unlike those of typical preponderance curves. These findings are in fairly close agreement with the theoretical curves obtained from the standard leads by the procedure suggested by Wilson and Herrmann (1922). Similar experiments were performed by Cohn and Raisbeck (1922b) on two cases of definite ventricular preponderance, one right-sided and the other left-sided. The results, however, were rather anomalous and difficult to interpret, though it seemed that normal curves could be obtained from these abnormal hearts with certain degrees of rotation. In criticism of this method, it may be pointed out that the curves from any triangular system of leads taken correctly by the convention of the three standard limb leads will of necessity obey the equation Lead 11 = Lead 1 + Lead 111, but it does not follow that such curves can be analysed by the equilateral triangle method. This method of analysis is only justifiable when the apices of the triangle, as well as being equidistant from each other, are also equidistant from the heart, or so remote from it as to be practically so. In many positions of Cohn and Raisbeck's triangle, certain apices, particularly on the left side of the chest, were much nearer the heart than others. This would presumably be even more noticeable in the enlarged hearts and in all probability accounted for the anomalous results in these cases.

One important fact which emerges from a study of these early articles is that although it had been pointed out by Einthoven et al. (1913) that a rotation of the heart around its longitudinal axis could produce striking changes in the electrocardiogram by projection of a sagittal potential on the frontal plane, no real allowance had been made for the possible effects of such a rotation in considering the problem of axis deviation and ventricular preponderance. Presumably this was because such effects cannot be calculated by the equilateral triangle theory as applied to the three standard leads, since this only holds for events in the frontal plane. Nevertheless in theory at least such a rotation could account for all the differences listed by Herrmann and Wilson (1922) between the effects of rotation around the antero-posterior axis and the observed findings in ventricular preponderance and particularly for the amount of rotation required to produce such curves, and for the alterations in the size of the manifest potential.

Variations in the amplitude and direction of the QRS complex and notching of the R and S waves on shifting from the dorsal recumbent to the right or left lateral posture were noted by Carter and Dieuaide (1921). In normal persons these changes were usually found in leads 1 and 111, while in patients with heart disease they were often most obvious in leads 1 and 11. As had already been suggested by Dieuaide (1921), alteration in the direction of the electrical axis was held to be responsible. In accordance with the equilateral triangle theory, the lead most affected was that which was most nearly perpendicular to the line of the axis, and in the normal heart this was usually lead 111, whereas in ventricular preponderance it was more likely to be lead 11. It also followed from the relationship of the sides of the triangle to each other, that in any given case, one of the leads would be obviously affected, another one somewhat less so and the remaining one would be practically unchanged. Further observations on changes in the electrocardiogram on turning the reclining subject from the right side to the left side were made by Dieuaide (1925). Changes were found in all the normal cases studied, though the actual number is not stated; and in most cases of heart disease the changes were even more striking. All the waves were affected to some extent, but especially the QRS complex. The type of change was not specified, but all the illustrative tracings show a tendency to right axis deviation when lying on the left side. It was also noted that respiration had a very obvious effect on the tracings in the lateral positions. In his series of fifty cases of heart disease, a small number showed no shift and in this group those who came to autopsy had mediastino-pericardial adhesions; a larger number had clinical signs of "adherent pericardium" but a marked shift in the electrocardiogram, and none of the post-mortem cases in this latter group had adhesions of both the pericardium and mediastinum. On these findings, he suggested that such fixation of the electrical axis might be useful as a test for this lesion.

This conclusion was questioned by Jones and Roberts (1929), who found that even in normal individuals, the shift of the electrical axis on changing from the right lateral to the left lateral posture was both slight and variable. Thus in some cases, the right lateral posture was associated with curves of right-sided preponderance, and the left lateral posture with left-sided preponderance as described by Einthoven et al. (1913), while in others the reverse was the case as had been found by Dieuaide (1925). Deep respiration in these postures, however, produced more obvious changes, the amount of movement of the electrical axis being greater in the right lateral than in the left lateral posture. It was suggested that the apparent discrepancies were due to the records being taken in different respiratory phases. In cases of adherent pericardium, respiratory axis shifts in any posture were negligible, and as this was particularly striking in the standing posture as compared with the findings in normal individuals it was considered that this respiratory test was much more reliable than the postural one already described by Dieuaide (1925).

Similar criticism of Dieuaide's test was made by Sampson and Rosenblum (1934). In a series of normal cases they found the shift in axis to be 5° to 55° in range on changing from right to left lateral posture;

in four out of five cases of proved mediastino-pericarditis, there was also a considerable shift of axis and only in one case with widespread involvement of the diaphragm was the axis fixed. They agreed with Dieuaide (1925) that the electrical axis shifted to the right in the left lateral recumbent posture.

This question was also studied by France (1938). In an analysis of thirty-eight cases with autopsy reports and electrocardiographic tests in the right and left lateral postures, he failed to find any correlation between fixation of the electrical axis and adhesive pericarditis.

An important contribution to the subject was made by Nathanson (1931) who recorded the standard leads in the dorsal recumbent, left lateral and right lateral postures in a series of sixty cases, some of whom were normal, and the others cardiac cases without fixation of the apex. In approximately 90 per cent there were definite changes particularly in the QRS complexes in leads 1 and 111; the other waves in these leads sometimes showed slight changes. In no case was there a significant alteration in any of the waves in lead 11. The most consistent changes occurred on shifting from the recumbent to the left lateral posture, which caused right axis deviation in 83 per cent of cases, left axis deviation in 6 per cent and no change in 11 per cent. Shifting from the recumbent to the right lateral posture produced more variable results, namely, left axis deviation in 35 per cent, right axis deviation in 35 per cent, and no change in 30 per cent. He stated that in view of the findings in the left lateral posture, a pure rotation of the heart around its antero-posterior axis could not account for all the changes observed. A possible clockwise rotation of the heart to the right around its antero-posterior axis due to upward movement of the diaphragm in the left lateral posture was also eliminated by radiological examination. It was concluded therefore that in the lateral postures, rotation of the heart around both its longitudinal and antero-posterior axes could occur. In the left lateral posture longitudinal rotation usually predominated though occasionally antero-posterior rotation might have the greater effect, while in about 10 per cent the two types neutralised each other. In the right lateral posture, however, there was an approximately even distribution of effects, for each variety of rotation predominated in about one third of cases and neutralisation occurred in the remaining one third. From his arguments it would appear that he considered that the left lateral posture caused counter-clockwise rotation about the antero-posterior axis and clockwise rotation about the longitudinal axis, while the right lateral posture produced exactly opposite rotations. This is in agreement with the ideas of Meek and Wilson (1925) which are discussed later in this section but is contrary to the findings of Einthoven et al.(1913).

The effect of changes in posture on the standard leads in bundle branch block was investigated by Kissin et al.(1933). They found some alteration in the direction of the electrical axis in all the six cases studied and in two of them there was an obvious change. This consisted in a reversal of the QRS complex in lead 111 from negative to positive and a decrease in amplitude of the QRS complex in lead 1 on shifting from the sitting or recumbent postures to the left lateral posture. As this converted the pattern from one of right bundle branch block (old terminology) to one of indeterminate type, they concluded that the position of the heart was a potent factor in deciding the standard lead appearances of human bundle branch block.

A fairly comprehensive study of postural effects on the standard leads in seven normal individuals was made by Katz and Robinow (1936). They found that shifting from the supine to the left lateral posture always produced a right axis shift, while from the supine to the right lateral or to the prone posture produced variable results. A change from the right lateral to the left lateral posture almost invariably caused a right axis shift and never a left shift. A change from the right lateral to the prone posture might cause left, right or no axis shift, whereas a change from the left lateral to the prone posture always caused a left axis shift.

Finally, the change from the supine to the sitting posture usually caused a left axis shift. Many of the results seemed to be in disagreement with the equilateral triangle theory and therefore though the underlying cause was admitted to be a change in the position of the heart, due to rotation around one or more of its axes, this was thought to produce its effect on the electrocardiogram mainly by a reorientation of the heart with respect to the differing electrical resistances of the various tissues surrounding it. A similar explanation was offered by Sigler (1938) to account for the differences which he observed in the standard leads on shifting from the recumbent to the sitting or standing postures. In his series the normal cases showed a tendency for the QRS axis to move to the right and the axis of the T wave to move to the left on adopting the sitting or standing posture, while the reverse occurred in the cases with diseased hearts.

A few observations have been made with regard to the effect of posture on the bipolar chest leads. Thus, Sigler (1938), in the article already referred to, noted some minor changes in lead 1VF in many of his cases but no detailed analysis was given. Lead 1VF was also studied in five normal cases by Robinson et al. (1939) in the supine, sitting and lateral postures. It was stated that while slight changes occurred in all cases, there were only two instances of significant alteration, once when a subject moved from the right to the left lateral posture, and in another case on moving from the recumbent to the sitting posture. In each case there was an increase in the R wave and disappearance of the S wave in lead lVF. Stewart and Bailey (1939) recorded three chest leads with the indifferent electrode on the back in a series of sixteen cases in the supine, sitting and left lateral postures. They found a progressive decrease in the R and T waves and sometimes also in the S wave as the subject changed from the supine to the sitting and to the left lateral posture in that order. In some instances an upright T wave became diphasic and a diphasic T wave became negative. The changes occurred in both normal and abnormal cases and were most obvious in the apical lead. The effect of passive tilting from the horizontal to the 75° head up position was studied in a series of ten normal individuals by Mayerson and Davis (1942), using the three standard leads and lead lVF. The main changes were found to be an increase of the P waves in leads 11 and 111, a decrease of the T waves in the three standard leads and in lead lVF, a shift of the QRS axis to the right in the standard leads and a decrease in the amplitude of the QRS complex in lead lVF. These changes were thought to be due partly to alteration in position of the heart and partly to increased sympathetic activity caused by a diminished venous return in the 75° head up posture.

As regards the unipolar leads, the only postural study so far reported has been that of Jones and Feil (1948). They have demonstrated that considerable shifts of the electrical axis in the standard leads can occur in some cases of bundle branch block, particularly of the left type, on turning from the supine to the lateral posture and that the electrical position of the heart as judged from the unipolar limb leads may also be changed. The unipolar precordial leads, however, show no appreciable alteration in pattern.

Other factors known to influence the position of the heart.

Although not directly related to the subject of postural changes, several other factors known to influence the electrocardiogram through a change in the position of the heart may now be considered briefly.

(a) Bodily habitus.

It has long been known (Waller, 1913d) that the thin asthenic type of individual usually has a vertical heart which is associated with a tendency to right axis deviation in the standard lead electrocardiogram. In contrast, the stocky, sthenic type of individual usually has a more transversely-lying heart which is associated with a tendency to left axis deviation.

(b) Obesity.

Uncomplicated obesity is usually associated with a high position of the diaphragm and a transversely disposed heart, which results in a tendency to left axis deviation with frequent flattening or inversion of the P and T waves in lead 111 (Master and Oppenheimer, 1929; Proger, 1931; Bland and White, 1931). With reduction in weight, the electrical axis in many cases shows a subsequent shift to the right.

(c) Pregnancy.

Numerous studies of the standard lead electrocardiogram in pregnancy have shown that in the later months, with elevation of the diaphragm by the gravid uterus and consequent transverse position of the heart, a tendency to left axis deviation manifests itself (Smith, 1922; Carr and Palmer, 1932; Landt and Benjamin, 1936). Many cases in addition develop a large Q wave and flattened or inverted P and T waves in lead 111 (Pardee, 1930; Carr et al., 1933; Feldman and Hill, 1934; Hollander and Crawford, 1943). In every case the electrocardiogram rapidly returns to normal immediately after delivery.

(d) <u>Displacement of the heart by thoracic and spinal deformities.</u>

Investigations of the electrocardiogram in cases with deformity of the thoracic cage such as kypho-scoliosis and "funnel" chest have shown that though there may be radiological evidence of displacement of the heart, there is usually little or no concomitant disturbance in the standard lead electrocardiogram (Edeiken and Wolferth, 1932; Edeiken, 1933; Adorno and White, 1945). This has been attributed to such displacement of the heart occurring as a whole without any rotation, or to the mutually antagonistic effects of simultaneous rotation around both the antero-posterior and longitudinal axes.

(e) <u>Intra-thoracic lesions and operative procedures.</u>

It has been noted that right-sided pleural effusion may be associated with a more transverse position of the heart and consequent tendency to complete inversion of lead 111 (Bland and White, 1931). On the other hand Lewis (1925b) has stated that neither pleural effusion nor artificial pneumothorax has any significant effect on the standard leads. Electrocardiographic investigations before and after various intra-thoracic operations including thoracoplasty, phrenicectomy and artificial pneumothorax have been carried out but have yielded no information of any import (Bettman and Priest, 1930; Hansen and Maly, 1933 and 1934).

(f) Intra-abdominal lesions and operative procedures.

Inversion of all the waves in lead 111 attributable to a high position of the diaphragm with transverse heart has been found in such intra-abdominal conditions as ascites, splenomegaly, hepatomegaly and fibromyoma (Bland and White, 1931). Elevation of the diaphragm by therapeutic pneumoperitoneum is associated with the development of a deep Q wave and inversion of the T wave in lead 111, with subsequent reversion to normal on descent of the diaphragm (Benatt and Berg, 1945). These changes seem to be due mainly to counter-clockwise rotation of the heart around its antero-posterior axis although there is also thought to be some degree of forward rotation of the apex around the transverse axis.

Conclusion.

A consideration of the above factors leads to the general conclusion that counter-clockwise rotation of the heart around its transverse axis is associated with left axis deviation and with the not infrequent development of a deep Q wave and inversion of the P and T waves in lead 111.

Animal and Cadaveric Studies.

From time to time various experimental procedures have been devised with a view to elucidating the influence of the position of the heart on the electrocardiogram. The earliest work of this kind was carried out by Boden and Neukirch (1918). Isolated perfused canine and human hearts were placed in a vessel of saline solution to which were attached three electrodes arranged according to the equilateral triangle schema. It was then possible to alter the position of the heart relative to the leads in any desired direction. Minor displacements of the heart as a whole were found to produce little or no effect, but any rotation was invariably accompanied by obvious changes in the electrocardiogram. Using modern terminology counter-clockwise rotation around either the antero-posterior or longitudinal axis resulted in left axis deviation, and clockwise rotation in right axis deviation. Owing to the highly artificial nature of these experiments, however, the conclusions were not generally acceptable (Herrmann and Wilson, 1922). Some time later Meek and Wilson (1925) by the use of suitable surgical procedures were able to study the effect of rotation of the dog's heart in situ around the antero-posterior and longitudinal axes. Not only did they fully corroborate the findings of Boden and Neukirch (1918), but they also demonstrated that the effect of a rotation around one of these axes could be neutralised by an appropriate counter-rotation around the other axis. They further stated that their observations did not seem to be in agreement with the explanation given by Einthoven et al (1913) for the frequent increase in the S wave in lead 1 with change of posture from the left lateral to the right lateral, in so far as such a manoeuvre should be accompanied by a counter-clockwise rotation of the heart around its longitudinal axis. Experimentally however, this type of rotation produced precisely the opposite changes in the S wave in lead 1, namely a diminution or disappearance. This criticism is not valid however, for in the first place Einthoven and his colleagues did not actually specify the direction in which the longitudinal rotation was supposed to occur, and secondly simple clinical observation supplies grounds for believing that the postural rotation is more likely to be in a clockwise direction. Thus it is recognised that when a normal person lies on his left side the apex impulse is not only displaced to the left but also becomes more obvious and forceful, whereas when he turns on to his right side it may be displaced slightly to the right, but it also becomes at the same time much less obvious and forceful. This would suggest that in turning from the left side to the right side the apex tends to recede from the chest wall, i.e. that there is a clockwise rotation of the heart around its longitudinal axis. It may be noted that this interpretation is also borne out by a consideration of the effect of this particular change of posture on the chest leads, as will be shown in a subsequent section of this thesis. If this is the correct explanation, then of course the clinical findings of Einthoven and his colleagues, and the experimental results of Meek and Wilson, are in complete accord.

The first reference to the effect of rotation of the heart around its transverse axis seems to have been made by Otto (1928). He maintained that the voltage in all three standard limb leads should diminish in proportion to the angle of inclination between the plane of the leads and the electrical axis, and he was able to illustrate this by tilting the exposed canine heart around its transverse axis. His statement is however much too catagorical, for such diminution will necessarily occur only if the actual resultant potential of the heart lies in or parallel to the frontal plane. Otherwise at some stage in the rotation there will be an increase in the voltage due to an increase in the manifest potential in the frontal plane.

In a series of experiments on dogs, Katz and Ackerman (1932) studied the effects of rotation of the heart around its three axes on the appearances in the limb leads of extra-systoles produced by artificial stimulation of fixed points on the ventricles. Rotation around the transverse axis, which had to be limited necessarily to 50° upwards from the horizontal, was associated with diminution in the size of the complexes. Rotation around the antero-posterior axis caused a shift of the electrical axis in the same direction as the anatomical axis, and in some instances resulted in reversal of the QRS complex. The most profound effect however was due to rotation around the longitudinal axis, for in this case reversal of the QRS complex was practically always produced. Furthermore, when clockwise rotation around the longitudinal axis was combined with counter-clockwise rotation around the antero-posterior axis or vice versa, the effect of the antero-posterior rotation was overshadowed and the electrical axis shifted in the opposite direction to the anatomical axis. Similar studies in experimental bundle branch lesions in dogs (Ackerman and Katz, 1933) gave analagous results. Thus reversal of the direction of the QRS complex in leads 1 or 111 could occur with uncomplicated antero-posterior rotation but was invariable when this was combined with an appropriate longitudinal rotation i.e. when both rotations were made in the clockwise or counter-clockwise directions respectively. It was therefore suggested that the terms right and left as applied to bundle branch block curves should be abandoned.

Similar experiments on artificially produced bundle branch block in dogs and monkeys were performed by

Foster (1935) who also found that rotation of the heart, particularly round its longitudinal axis, could cause alterations in the ventricular deflections in the standard leads, including reversal of the direction of the QRS complex in leads 1 or 111. With the amount of rotation employed however one type of pattern was not transformed to the other type but was merely rendered "discordant", the direction of the electrical axis still remaining the same. He pointed out that theoretically the electrical axis would have to be displaced more than 180° for complete metamorphosis to occur and he showed that this was possible experimentally by reversing the positions of the ventricles. Since such extreme degrees of rotation were unlikely to occur naturally, he disagreed with the conclusion of Ackerman and Katz (1933) regarding the unsuitability of the right and left terminology.

In a series of experimental studies, Kountz et al (1935 and 1935a,b) investigated the standard lead curves in humans, dogs and monkeys with respect to induced extra-systoles, experimental bundle branch block and changes in position of the heart. With revived perfused human hearts in normal position (Kountz et al, 1935) they confirmed the results of Barker et al (1930) with regard to induced extra-systoles and also the predictions of the latter with regard to the curves of bundle branch block. They also found that in the dog clockwise rotation of the heart around its longitudinal axis caused right axis deviation and counter-clockwise rotation left axis deviation. By placing a perfused canine heart in the human pericardial cavity in exactly the same position with regard to ventricles and septum as the original heart had been, they obtained tracings of induced extra-systoles and experimental bundle branch block similar to those obtained with the revived human heart (Kountz et al, 1935a). They also showed that owing to the shape of the canine chest with its relatively deep antero-posterior diameter, there was a very considerable backward displacement of the heart with some degree of clockwise rotation when the animal was placed in the usual dorsal experimental position with the chest opened. This was held to account for the apparent discrepancy between the human and canine standard lead curves. In experiments with monkeys in the dorsal decubitus the tracings of induced extra-systoles and bundle branch block closely resembled those obtained from the human heart (Kountz et al, 1935b). This was because the configuration of the chest in the monkey is more or less the same as in man and therefore no appreciable displacement of the heart occurs in the dorsal experimental position.

Conclusion.

From this experimental work the following inferences may be drawn with regard to the standard leads:-

(a) Within reasonable limits a displacement of the heart without rotation has no significant effect.

(b) Rotation of the heart around any of its three axes invariably produces striking changes:-

1. <u>Antero-posterior axis.</u>

Clockwise rotation is associated with right axis deviation.

Counter-clockwise rotation is associated with left axis deviation.

2. <u>Longitudinal axis</u>.

Clockwise rotation is associated with right axis deviation.

Counter-clockwise rotation is associated with left axis deviation.

3. <u>Transverse axis</u>.

Rotation around this axis may be associated with decrease in voltage in all leads but there is no definite relation to axis deviation.

The electrocardiographic position of the heart.

From a consideration of the unipolar limb leads, Wilson et al (1944) have described six possible positions of the heart as follows:-

1. Vertical position.

The ventricular complexes of VL resemble those of V1 and V2, while those of VF resemble V5 and V6.

2. Semi-vertical position.

The ventricular complexes of VF resemble those of V5 and V6, while those of VL are small.

3. Intermediate position.

The ventricular complexes of both VL and VF are similar and resemble those of V5 and V6.

4. Semi-horizontal position.

The ventricular complexes of VL resemble those of V5 and V6, while those of VF are small.

5. Horizontal position.

The ventricular complexes of VL resemble those of V5 and V6, while those of VF resemble V1 and V2.

6. Indeterminate position.

No obvious relationship exists between the ventricular complexes of the unipolar limb leads and those of the precordial leads.

It is pointed out that a fairly close correlation between the anatomical position of the heart and its electrocardiographic position as defined above exists in the normal heart, in bundle branch block and in preponderance of the right or left ventricles.

Rotation of the heart and its effect on the unipolar patterns.

The theoretical effects on the standard leads of rotation of the heart around three axes, (a) the antero-posterior, (b) the longitudinal and (c) the transverse, were discussed by Gardberg and Ashman (1943). These ideas have been applied to the unipolar leads by Goldberger (1949b), whose conclusions may be summarised as follows:-

(a) Antero-posterior axis.

Clockwise rotation around this axis causes the heart to become more vertical in position, while counter-clockwise rotation causes it to become more horizontal.

In a vertical heart, lead aVL has a QS or an rS pattern. In a horizontal heart, lead aVL has a qR or a QR pattern.

(b) Longitudinal axis.

Clockwise rotation of the heart around this axis causes the right ventricle to lie more anteriorly and the left ventricle more posteriorly. Counter-clockwise rotation causes the reverse changes.

Moderate clockwise rotation is associated with an rS pattern in lead aVR.

Marked clockwise rotation is associated with a QR, Qr or qR pattern in lead aVR.

Moderate counter-clockwise rotation is associated with commencement of a qR pattern in leads

V3 or V4, while leads V1 and V2 show an rS pattern.

Marked counter-clockwise rotation is associated with commencement of qR pattern in lead V2, while lead V1 shows an rS pattern.

(c) Transverse axis.

Forward or backward rotation of the apex of the heart can occur round this axis.

With forward rotation of the apex, lead aVF shows a qR pattern.

With backward rotation of the apex, lead aVF usually shows an rS or RS pattern.

The combinations usually encountered are listed as follows:-

1. The normal vertical heart.

A. The normal vertical heart with moderate counter-clockwise rotation and with forward rotation of the apex.

B. The normal vertical heart with moderate clockwise rotation and with forward rotation of the apex.

C. The normal vertical heart with marked clockwise rotation and with forward rotation of the apex.

D. The normal vertical heart with marked clockwise rotation and with backward rotation of the apex.

11. The normal horizontal heart.

A. The normal horizontal heart with moderate counter-clockwise rotation and with forward rotation of the apex.

B. The normal horizontal heart with marked counter-clockwise rotation.

(This type is relatively rare).

C. The normal horizontal heart with moderate clockwise rotation.

D. The normal horizontal heart with marked clockwise rotation and with forward rotation of the apex.

E. The normal horizontal heart with marked clockwise rotation and with backward rotation of the apex.

In recent years, therefore, the position of the heart has come to be regarded as of paramount importance in the interpretation of the various patterns of the unipolar limb and chest leads. Many of the concepts are based on purely theoretical grounds and it seemed desirable that some practical confirmation of these should be obtained. It was decided that one of the most feasible clinical approaches to the problem would be a comprehensive study of the effect of postural variations on the unipolar leads. It was also hoped that some light might be shed on the conflicting reports of previous observers on the effects of posture on the standard leads.

SECTION 2.

Method and scope of investigation.

The general object of the experiments described in this part of the thesis was to assess the effect of alteration of posture on the electrocardiogram and to determine whether the electrocardiographic changes could be interpreted rationally by the unipolar method on the basis of rotation and displacement of the heart.

Selection of Cases.

The total number of cases studied was fifty-six of whom seven were females.

As it was considered that postural effects in health might differ from those in disease, it was decided to investigate two groups of subjects.

The first group comprised thirty-six healthy adults of whom three were females. The ages of the subjects ranged from 15 to 45 years. In the subsequent analysis and presentation of the results this group is referred to as the normal group.

The second group comprised twenty subjects who were considered to be abnormal. The individual diagnoses are shown in the table on page 233. Two main factors were considered in choosing these cases. In the first place, on clinical grounds alone, the object was to obtain a representative selection of cardiovascular or related syndromes. Secondly, since the

TABLE

DIAGNOSIS IN TWENTY ABNORMAL CASES STUDIED IN PART IV

DIAGNOSIS		NUMBER OF CASES MALE	NUMBER OF CASES FEMALE	PLATE NUMBERS
CORONARY INSUFFICIENCY		I	0	I70 a,b
MYOCARDIAL INFARCTION	ANTERIOR	I	0	I7I a,b
	ANTERO-LATERAL	I	0	I80 a,b
	POSTERIOR	2	0	I72 a,b; I79 a,b
BUNDLE BRANCH BLOCK	RIGHT	I	0	I78 a,b
	LEFT (INCOMPLETE)	I	0	I84 a,b
MITRAL STENOSIS	CHRONIC ADHESIVE PERICARDITIS	I	0	I75 a,b
	AURICULAR FIBRILLATION CONGESTIVE HEART FAILURE	I	0	I82 a,b,c
ESSENTIAL HYPERTENSION		0	2	I69 a,b; I74 a,b
CHRONIC BRONCHITIS		I	0	I85 a,b
CHRONIC BRONCHITIS with EMPHYSEMA		2	0	I68 a,b; I73 a,b,c
PNEUMOCONIOSIS		I	0	I8I a,b
THYROTOXICOSIS		0	I	I76 a,b
NEURO-CIRCULATORY ASTHENIA		I	I	I67 a,b;c; I83 a,b
CHRONIC CHOLECYSTITIS		I	0	I86 a,b
IDIOPATHIC STEATORRHOEA		I	0	I77 a,b,c

investigations on the normal group had aroused particular interest in the T wave changes, an endeavour was made to include as many varieties as possible of abnormal T wave appearances in the standard leads. In the subsequent analysis and presentation of results, this group is referred to as the abnormal group.

Method.

The following seven postures were studied in all cases.

A. Sitting.

B. Standing.

C. Lying on the back in the 45° head up position.

D. Lying on the back in the horizontal position (supine).

E. Lying on the right side in the horizontal position.

F. Lying on the left side in the horizontal position.

G. Lying face down in the horizontal position (prone).

In twenty-three of the normal cases, an additional posture (H) was studied, with the subject lying on his back in the 45° head down position. It was considered inadvisable to study the abnormal cases in this last posture.

In all cases the following leads were recorded in each posture:-

(a) The three standard limb leads.

(b) The three unipolar limb leads.

(c) The six unipolar precordial leads V1 to V6.

In the sub-group of twenty-three normal cases already referred to, the unipolar limb leads were recorded by the unaugmented Goldberger method; in all the other cases, they were taken by the augmented Goldberger method. In four of the abnormal cases, additional unipolar limb leads were taken by the unaugmented Wilson method.

To facilitate the recording of all these leads, the electrode belt and the multiple switch box were employed as described in Part 1, Section 2.

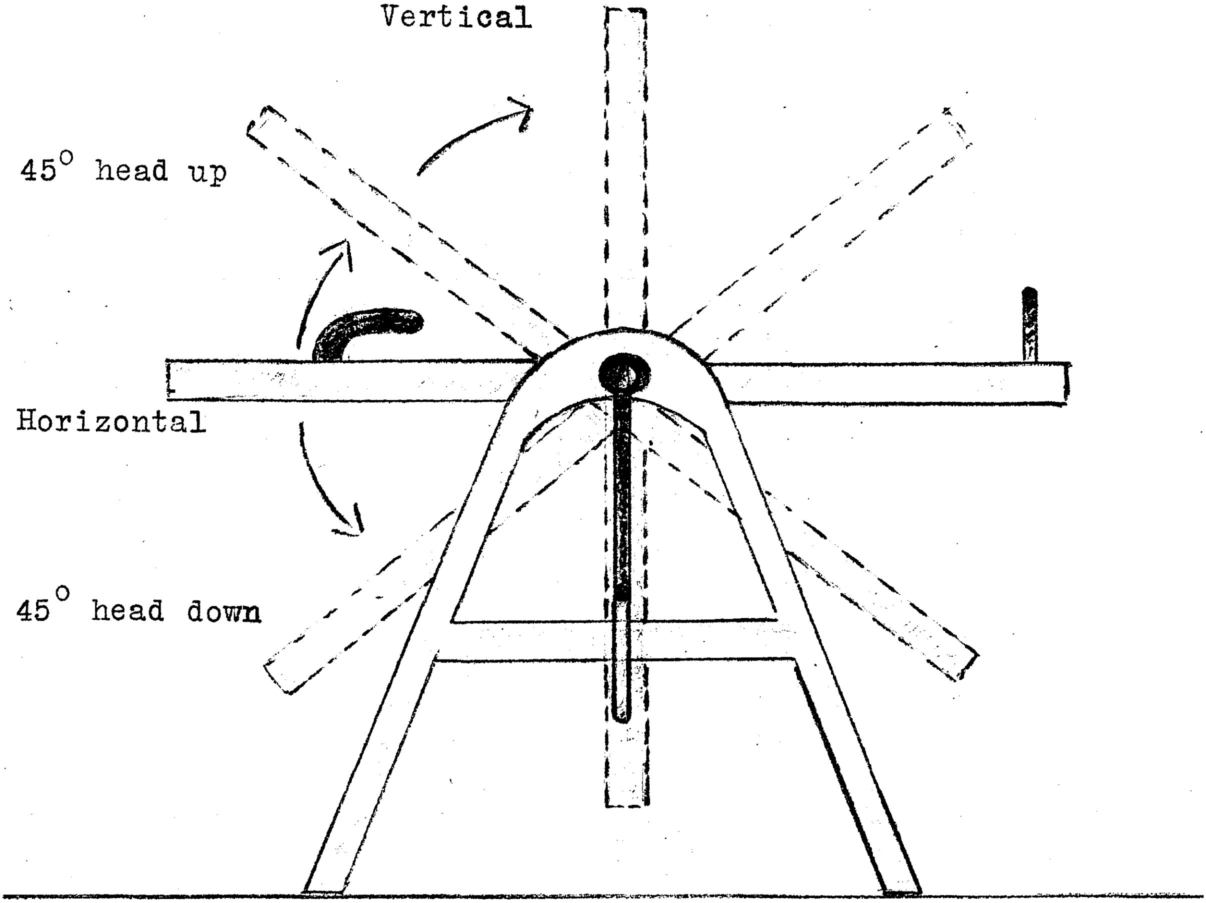
A suitably designed tilting table was used to obtain uniformity of the postures.

Description of Tilting Table.

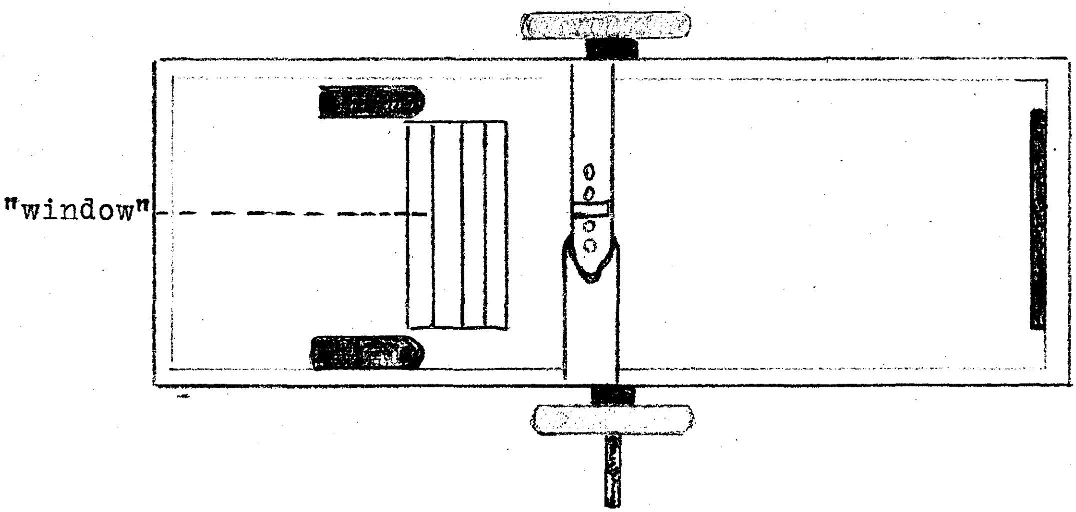
This was a manually operated tilting table (fig. I7). It had adjustable supports for the feet and shoulders, and also a retaining abdominal belt, so that the subject would be securely held in the desired positions. The part of the table underlying the chest was constructed of several strips, each three inches in breadth, which could be removed so as to form a gap at any required level. The objects of this arrangement were (a) to accommodate the chest electrodes when the subject was lying in the lateral or prone postures and (b) to allow electrodes to be applied to the posterior aspect of the chest when the subject was lying in the supine posture.

The table could be fixed in the following positions:-

1. Vertical position.
2. 45° head up position.
3. Horizontal position.
4. 45° head down position.



a. Side elevation of table



b. Plan of top of table

Fig. I7

Procedure.

In each case, the investigation was commenced after the subject had been sitting at rest in a chair for about fifteen minutes and at least two hours after his last meal. A brief explanation of the general purpose and method of examination was given. The subject then lay on his back on the table, adjustments of the supporting pieces were made for his size and he was tilted into the experimental positions to accustom him to the procedure. He then resumed the sitting posture while the limb and chest electrodes were fitted on and the lead connections to the switch box were made as described in Part 1, Section 2.

The twelve leads already detailed were recorded with the subject still sitting in the chair (sitting posture). He then lay on the table and the same series of leads was taken in the following successive postures:-

1. Standing posture (vertical).
2. 45° head up posture.
3. Recumbent posture (horizontal).
4. 45° head down posture (in twenty-three normal cases only).
5. Right lateral posture (horizontal).
6. Left lateral posture (horizontal).
7. Prone posture (horizontal).

The average time required for the investigation of each posture was fifteen minutes. The order of the postures was originally decided on theoretical grounds to eliminate or at least minimise any possible effects of postural hypotension. It proved satisfactory as no case of this was encountered in the entire series though the subjects were all instructed beforehand to report at once any premonitory symptom such as giddiness or faintness.

For the 45° head down posture, the leads were recorded in groups of three at a time and the subject was returned to the horizontal posture for a few minutes between each stage. No untoward symptoms were experienced by any individual during this process. In this same group of twenty-three normal cases, the order of taking the lateral postures was reversed as compared with the rest of the series, the left lateral posture being investigated before the right lateral. The reason for this was to exclude any possible effect of prolonged lying on one side. It was considered advisable to do this in view of the contradictory reports in the literature regarding the appearances in the standard limb leads on changing from one lateral posture to the other. Care was also taken to ensure that in the lateral postures the transverse axis of the chest was perpendicular to the horizontal plane of the table and that the subject was not inclined either forwards or backwards.

Arrangement and Description of Illustrative Plates.

The tracings from the thirty-six normal cases are shown in plates 131 to 166 and those from the twenty abnormal cases in plates 167 to 186. Each case has one plate number, but most of the plates have two parts, (a) containing the standard limb leads and (b) containing the unipolar limb and precordial leads. In the four abnormal cases where additional unipolar limb leads were taken, the plates have three parts, (a) containing the standard limb leads, (b) the unipolar limb leads and (c) the unipolar precordial leads (plates 167, 173, 177 and 182). In every case, two representative complexes are shown in the standard limb leads for each posture so that any changes in the heart rate may be seen.

The standard limb leads, unipolar limb leads and unipolar precordial leads are dealt with separately. The appearances in the recumbent posture in each instance are described first and are treated as control observations. Then the changes are given for the postures involving "vertical rotation" of the subject, namely the sitting, standing and 45° head up postures and the 45° head down posture where applicable. Finally, the changes are described for the postures involving "horizontal rotation" of the subject, namely the two lateral postures and the prone posture.

The first twenty-three normal cases (plates 131 to 153) are those in whom the additional 45° head down posture was studied and in whom the unaugmented unipolar limb leads were recorded. In these cases also, the left lateral posture was investigated before the right lateral, in contrast to the other thirteen normal and the twenty abnormal cases. The lettering of the tracings in these twenty-three cases differs therefore from that in the other thirty-three cases, but the accompanying descriptions are appropriately lettered to avoid any ambiguity.

In each of the groups, the individual cases are arranged according to the electrocardiographic position of the heart in the recumbent posture. Thus the vertical hearts are placed before the horizontal hearts and within these main divisions the order is moderate counter-clockwise, moderate clockwise and marked clockwise depending on the amount of rotation around the longitudinal axis.

SECTION 3.

The Effect of Posture on the Heart Rate.

In this section the effect of posture on the heart rate in thirty-six normal and twenty abnormal cases is described. Seven postures were studied in every case, namely, sitting (A), standing (B), 45° head up (C), supine (D), right lateral (E), left lateral (F), prone (G). In twenty-three of the normal cases the 45° head down posture (H) was also studied. For comparative purposes the rate in the supine posture was taken as the control. Differences exceeding plus or minus ten beats per minute were considered significant.

Results.

Normal Cases.

D: Supine.

The heart rate in thirty-five of the cases ranged from 52 to 90 beats per minute. The remaining case had a heart rate of 130 per minute for which no pathological cause could be found.

A: Sitting.

In eighteen cases there was no significant change in the heart rate. The other eighteen cases showed an increase in the heart rate ranging from 11 to 23 beats per minute with an average increase of 16 beats per minute.

B: Standing.

Only one case showed no significant change in the heart rate. The remaining thirty-five showed an increase ranging from 12 to 55 beats per minute with an average increase of 24 beats per minute.

C: 45° head up.

Five cases showed no significant change. The remaining thirty-one showed an increase ranging from 11 to 36 beats per minute with an average increase of 18 beats per minute.

E: Right Lateral.

One case showed an increase of 15 beats per minute and one case showed a decrease of 13 beats per minute. The remaining thirty-four cases showed no significant change.

F: Left Lateral.

One case showed an increase of 15 beats per minute and one case showed a decrease of 12 beats per minute. The remaining thirty-four cases showed no significant change.

G: Prone.

Six cases showed an increase of 13 to 15 beats per minute with an average increase of 14 beats per minute. The remaining thirty cases showed no significant change.

H: 45° head down.

Seven cases showed a decrease in the heart rate ranging from 11 to 19 beats per minute, with an average decrease of 13 beats per minute. The remaining sixteen cases showed no significant change.

Where increase or decrease in the heart rate occurred it bore no relationship to the initial heart rate.

Abnormal cases.

D: Supine.

The heart rate in the twenty cases ranged from 53 to 94 beats per minute.

A: Sitting.

In nine cases there was no significant change in the heart rate. The remaining eleven cases showed an increase in rate ranging from 11 to 42 beats per minute with an average increase of 18 beats per minute.

B: Standing.

Five cases showed no significant change in the heart rate. The remaining fifteen cases showed an increase ranging from 11 to 42 beats per minute with an average increase of 23 beats per minute.

C: 45° head up.

Eight cases showed no significant change. The remaining twelve cases showed an increase ranging from 11 to 32 beats per minute with an average increase of 18 beats per minute.

E: Right lateral.

One case showed an increase of 11 beats per minute. The remaining nineteen cases showed no significant change.

F: Left Lateral.

None of the twenty cases showed a significant change in the heart rate.

G: Prone.

Four cases showed an increase in the heart rate ranging from II to 20 beats per minute with an average increase of I4 beats per minute. The remaining sixteen cases showed no significant change.

Where increase in the heart rate occurred it bore no relationship to the initial heart rate.

One case of auricular fibrillation under treatment with digitalis showed no change in the heart rate in any of the postures.

One case with sinus block due to digitalis showed a significant increase in the heart rate in the standing and prone postures.

Conclusions.

Normal Cases.

In normal subjects when the heart rate in the supine posture is taken as the control, the sitting posture causes a significant increase in the heart rate in about half of the cases.

The standing posture is associated with an even greater increase in heart rate in practically every case.

The 45° head up posture also causes an increase in the heart rate in most cases though the increase is usually less than in the standing posture.

In the right and left lateral postures there is no alteration in the heart rate.

In a small number of cases the prone posture is associated with a moderate increase in heart rate.

In about one third of the cases the 45° head down posture causes a decrease in heart rate.

These changes are all independent of the value of the heart rate in the control posture.

Abnormal Cases.

In the abnormal cases the results in the sitting posture are similar to those in the normal cases.

In the standing and 45° head up postures increase in the heart rate seems to occur less frequently than in the normal cases, but when it does occur it is of the same order of magnitude.

In the right and left lateral and prone postures the results are similar to those in the normal series.

As in the normal cases the changes are all independent of the value of the heart rate in the control posture.

SECTION 4.

The Effect of Posture on the Normal Electrocardiogram.

1. Standard Limb Leads.

In this section the effects of alteration of posture on the standard limb leads in thirty-six normal cases are described. For comparative purposes the appearances in the supine posture (D) are taken as the control. The changes are described under the three headings QRS axis, P wave and T wave.

QRS axis.

The control tracings (D) show that eighteen cases have right axis deviation, six have left axis deviation and twelve have no axis deviation.

In the sitting posture (A) twenty-eight cases show a shift of the QRS axis to the right though in fourteen of them the shift is of relatively slight degree. Two cases show a slight shift of the QRS axis to the left. Six cases show no change.

In the standing posture (B) thirty-three cases show a shift of the QRS axis to the right though in eight of them the shift is of relatively slight degree. One case shows a shift of the QRS axis to the left. Two cases show no change.

In the 45° head up posture (C) thirty-three cases show a shift of the QRS axis to the right though in eleven of them it is of relatively slight degree. One case shows a slight shift of the QRS axis to the left. Two cases show no change.

In the 45° head down posture (H) all except one of the twenty-three cases show a shift of the QRS axis to the left though in six of them it is of relatively slight degree. The remaining case shows no change.

In the right lateral posture (E) twenty-five cases show a shift of the QRS axis to the left though in ten of them it is of relatively slight degree. Six cases show a shift of the QRS axis to the right though in four of them it is of relatively slight degree. Five cases show no change.

In the left lateral posture (F) thirty-one cases show a shift of the QRS axis to the right though in three of them it is of relatively slight degree. One case shows a slight shift of the QRS axis to the left. Four cases show no change.

In the prone posture (G) thirty-three cases show a shift of the QRS axis to the left though in thirteen of them it is of relatively slight degree. Three cases show no change.

P wave.

The control tracings (D) show that twenty-nine cases have upright P waves in all three leads, six cases have upright P waves in leads 1 and 11 and diphasic P waves in lead 111 and one case has an upright P wave in lead 1 and diphasic P waves in leads 11 and 111.

In the sitting posture (A) twenty-four cases show no change in the P waves. Eleven cases show an increase of the P waves in leads 11 and 111; in two of these the P wave in lead 111 is changed from diphasic to upright. In one case there is diminution of the P waves in leads 1 and 11.

In the standing posture (B) twenty-eight cases show an increase of the P waves in leads 11 and 111; in four of these the P wave in lead 111 is changed from diphasic to upright and in one case the P waves in leads 11 and 111 are changed from diphasic to upright. Eight cases show no change in the P waves.

In the 45° head up posture (C) the changes are very similar to those in the standing posture. Thus the same twenty-eight cases show increase of the P waves in leads 11 and 111; in four of these the P wave in lead 111 is changed from diphasic to upright and in one case the P waves in leads 11 and 111 are changed from diphasic to upright. The same eight cases show no change in the P waves.

In the 45° head down posture (H) twenty cases show no change in the P waves. Two cases show diminution of the P waves in leads 11 and 111; in one of these the P wave in lead 111 is changed from diphasic to inverted and in the other from upright to flat. One case shows diminution of the P wave in lead 111 alone.

In the right lateral posture (E) twenty-seven cases show no change in the P waves. The remaining nine cases show a variety of changes. Thus in four cases the P wave is increased in leads 11 and 111; in two cases it is increased in leads 1 and 11; in two cases it is increased in lead 11 alone; and in one case it is increased in lead 1 and diminished in lead 111.

In the left lateral posture (F) twenty-nine cases show no change in the P waves. The remaining seven cases show a variety of changes. Thus in four cases the P wave is increased in leads 11 and 111; in one case it is increased in lead 111 alone; in one case it is diminished in all three leads; and in one case it is diminished in lead 1 and increased in lead 111.

In the prone posture (G) thirty-one cases show no change in the P waves. The remaining five cases show a variety of changes. Thus in two cases the P wave is increased in leads 11 and 111; in one case it is increased in lead 11 alone; and in two cases it is diminished in lead 111 alone.

T wave.

The control tracings (D) show that thirty cases have upright T waves in all three leads; five cases have upright T waves in leads 1 and 11 and diphasic T waves in lead 111; one case has upright T waves in leads 1 and 11 and inverted T wave in lead 111.

Sitting posture (A).

Changes in the T waves occur in thirty-three of the thirty-six cases. The type of change may be classified as follows:

(1) The T wave becomes less positive in leads 11 and 111 in seventeen cases. These include one case in which an upright T in lead 111 becomes inverted, two cases in which an upright T in lead 111 becomes diphasic and one case in which a diphasic T in lead 111 becomes more negative.

(2) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in four cases. These include one case in which upright T waves in leads 11 and 111 become inverted, one case in which an upright T wave in lead 111 becomes diphasic and one case in which a diphasic T wave in lead 111 becomes more negative.

(3) The T wave becomes more positive in leads 1 and 11 and less positive in lead 111 in four cases. These include one case in which an inverted T in lead 111 becomes more negative.

(4) The T wave becomes more positive in lead 1 and less positive in lead 111 in four cases. These include one case in which an upright T in lead 111 becomes diphasic.

(5) The T wave becomes less positive in all leads in three cases. These comprise one case in which an

upright T wave in lead 111 becomes inverted, one case in which a diphasic T wave in lead 111 becomes inverted and one case in which a diphasic but mainly positive T wave in lead 111 becomes flat.

(6) The T wave becomes more positive in leads 11 and 111 in one case.

From this detailed analysis it is evident that changes in polarity of the T waves occur in nine cases. These comprise one case in which an upright T wave in leads 11 and 111 becomes inverted in both, two cases in which an upright T wave in lead 111 becomes inverted, four cases in which an upright T wave in lead 111 becomes diphasic, one case in which a diphasic T wave in lead 111 becomes flat and one case in which a diphasic T wave in lead 111 becomes inverted. The changes in polarity are therefore all consistent.

Standing posture (B).

Changes in the T waves occur in all thirty-six cases. The types of change are classified as follows:

(1) The T wave becomes less positive in leads 11 and 111 in sixteen cases. These include two cases in which upright T waves in leads 11 and 111 become inverted, one case in which upright T waves in leads 11 and 111 become flat in lead 11 and inverted in lead 111, one case in which an upright T wave in lead 11 becomes flat and a diphasic T wave in lead 111 becomes

inverted, two cases in which upright T waves in lead 111 become flat, one case in which an upright T wave in lead 111 becomes diphasic, three cases in which upright T waves in lead 111 become inverted and one case in which an inverted T wave in lead 111 becomes more negative.

(2) The T wave becomes less positive in all leads in nineteen cases. These include one case in which upright T waves in leads 11 and 111 become inverted, one case in which upright T waves in leads 11 and 111 become flat in lead 11 and inverted in lead 111, four cases in which upright T waves in lead 111 become flat, one case in which an upright T wave in lead 111 becomes diphasic, two cases in which upright T waves in lead 111 become inverted and three cases in which diphasic T waves in lead 111 become inverted.

(3) The T wave becomes less positive in leads 1 and 11 and more positive in lead 111 in one case. In this case a diphasic T wave in lead 111 becomes less negative.

From this detailed analysis it is evident that changes in polarity of the T waves occur in twenty-two cases. In six of them both lead 11 and lead 111 are affected; these comprise three cases in which upright T waves in leads 11 and 111 become inverted, two cases in which an upright T wave in lead 11 becomes flat and an upright T wave in lead 111 becomes inverted, and one case in which an upright T wave in lead 11 becomes flat and a diphasic T wave in lead 111 becomes inverted. In the remaining sixteen cases lead 111 alone is affected; these comprise six cases in which upright T waves in lead 111 become flat, two cases in which upright T waves in lead 111 become diphasic, five cases in which upright T waves in lead 111 become inverted and three cases in which diphasic T waves in lead 111 become inverted. The changes in polarity are therefore all consistent.

45° head up posture (C).

Changes in the T waves occur in all thirty-six cases. The types of change may be classified as follows:

(1) The T wave becomes less positive in leads 11 and 111 in seventeen cases. These include one case in which upright T waves in leads 11 and 111 become flat in lead 11 and inverted in lead 111, two cases in which upright T waves in lead 111 become inverted, one case in which a diphasic T wave in lead 111 becomes more negative and one case in which an inverted T wave in lead 111 becomes more negative. Of the seventeen cases in this group fifteen show a similar type of change in the standing posture; the remaining two cases show less positive T waves in all leads.

(2) The T wave becomes less positive in all leads in fifteen cases. These include one case in which an upright T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 111 becomes

diphasic, two cases in which diphasic T waves in lead 111 become inverted and one case in which a diphasic T wave in lead 111 becomes less positive. All the fifteen cases in this group show a similar type of change in the standing posture.

(3) The T wave becomes less positive in leads 1 and 11 in two cases.

(4) The T wave becomes more positive in lead 1 and less positive in lead 111 in one case.

(5) The T wave becomes less positive in leads 1 and 11 and more positive in lead 111 in one case. In this case a diphasic T wave in lead 111 becomes less negative. This case shows a similar type of change in the standing posture.

From this detailed analysis it is evident that changes in polarity of the T waves occur in seven cases. These comprise one case in which upright T waves in leads 11 and 111 become flat in lead 11 and inverted in lead 111, one case in which an upright T wave in lead 111 becomes diphasic, three cases in which upright T waves in lead 111 become inverted and two cases in which diphasic T waves in lead 111 become inverted. The changes in polarity are therefore all consistent. They are considerably less frequent and less marked than in the standing posture but are similar in type.

<u>45° head down posture (H)</u>.

Changes in the T waves occur in fifteen of the twenty-three cases. The types of change may be classified as follows:

(1) The T wave becomes more positive in lead 1 and less positive in lead 111 in six cases. These include one case in which an upright T wave in lead 111 becomes flat and two cases in which diphasic T waves in lead 111 become more negative.

(2) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in three cases. These include one case in which an upright T wave in lead 111 becomes flat.

(3) The T wave becomes more positive in leads 1 and 11 in three cases.

(4) The T wave becomes less positive in leads 11 and 111 in one case.

(5) The T wave becomes more positive in all leads in two cases.

From this detailed analysis it is evident that changes in polarity of the T waves occur in only two cases. In both, upright T waves in lead 111 become flat.

Right lateral posture (E).

Changes in the T waves occur in thirty-one of the thirty-six cases. The types of change may be classified as follows:

(1) The T wave becomes more positive in all leads in nine cases. These include one case in which a diphasic T wave in lead 111 becomes upright.

(2) The T wave becomes more positive in leads 11 and 111 in seven cases.

(3) The T wave becomes less positive in lead 1 and more positive in leads 11 and 111 in six cases. These include one case in which a diphasic T wave in lead 111 becomes upright.

(4) The T wave becomes less positive in lead 1 and more positive in lead 111 in three cases. These include one case in which a diphasic T wave in lead 111 becomes upright and one case in which a diphasic T wave in lead 111 becomes more positive.

(5) The T wave becomes less positive in leads 1 and 11 and more positive in lead 111 in one case.

(6) The T wave becomes less positive in leads 1 and 11 in one case.

(7) The T wave becomes more positive in leads 1 and 11 in three cases.

(8) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in one case.

From this detailed analysis it is evident that changes in polarity of the T waves occur in only three cases; in each case a diphasic T wave in lead 111 becomes upright. It is also clear that the changes in the T waves fall into three groups. (a) In nine cases the T wave becomes more positive in all leads. (b) In eighteen cases there is a shift of the axis of the T wave to the right. (c) In four cases there is a shift of the axis of the T wave to the left.

Left lateral posture (F).

Changes in the T waves occur in twenty-two of the thirty-six cases. The types of change may be classified as follows:

(1) The T wave becomes less positive in lead 1 and more positive in lead 111 in seven cases. These include one case in which a diphasic T wave in lead 111 becomes upright.

(2) The T wave becomes less positive in lead 1 and more positive in leads 11 and 111 in two cases.

(3) The T wave becomes more positive in leads 11 and 111 in five cases. These include two cases in which diphasic T waves in lead 111 become upright.

(4) The T wave becomes less positive in leads 1 and 11 and more positive in lead 111 in one case.

(5) The T wave becomes less positive in leads 1 and 11 in one case.

(6) The T wave becomes more positive in lead 1 and less positive in lead 111 in three cases. These include one case in which a diphasic T wave in lead 111 becomes more negative.

(7) The T wave becomes less positive in leads 11 and 111 in two cases.

(8) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in one case.

From this detailed analysis it is evident that changes in the polarity of the T waves occur in only three cases; in each case a diphasic T wave in lead 111 becomes upright. It is also clear that the changes in the T waves fall into two groups. (a) In sixteen cases there is a shift of the axis of the T wave to the right. (b) In six cases there is a shift of the axis of the T wave to the left.

Prone posture (G).

Changes in the T waves occur in thirty-two of the thirty-six cases. The types of change may be classified as follows:

(1) The T wave becomes more positive in lead 1 and less positive in lead 111 in fourteen cases. These include three cases in which positive T waves in lead 111 become flat, two cases in which diphasic T waves in lead 111 become more negative and one case in which a diphasic T wave in lead 111 becomes inverted.

(2) The T wave becomes more positive in leads 1 and 11 and less positive in lead 111 in seven cases. These include two cases in which upright T waves in lead 111 become diphasic and one case in which a diphasic T wave in lead 111 becomes less positive.

(3) The T wave becomes more positive in leads 1 and 11 in four cases.

(4) The T wave becomes less positive in leads 11 and 111 in three cases.

(5) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in one case.

(6) The T wave becomes less positive in all leads in one case. In this case a diphasic T wave in lead 111 becomes inverted.

(7) The T wave becomes less positive in leads 1 and 11 in one case.

(8) The T wave becomes more positive in leads 11 and 111 in one case.

From this detailed analysis it is evident that changes in polarity of the T waves occur in seven cases. These comprise three cases in which upright T waves in lead 111 become flat, two cases in which upright T waves in lead 111 become diphasic, and two cases in which diphasic T waves in lead 111 become inverted. The changes in polarity are therefore all consistent.

It is also clear that the changes in the T waves fall into two groups. (a) In thirty cases there is a shift of the axis of the T wave to the left. (b) In two cases there is a shift of the axis of the T wave to the right.

SECTION 5.

The Effect of Posture on the Normal Electrocardiogram.

11. Unipolar Limb Leads.

In this section the effects of alteration of posture on the unipolar limb leads in the thirty-six normal cases are described. For comparative purposes the appearances in the supine posture (D) are taken as the control. The changes are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The criteria for determining the position of the heart are the same as those already detailed in Part 111, Section 4.

The control tracings (D) show that in twenty-six cases the heart is vertical, in nine cases it is horizontal and in one case it is intermediate in position. This last case is so classified because both aVL and aVF have R patterns and the heart is therefore neither vertical nor horizontal. Of the twenty-six vertical hearts, eighteen show right axis deviation in the standard limb leads and eight show no axis deviation. Of the nine horizontal hearts six show left axis deviation and three show no axis deviation. The one intermediate heart shows no axis deviation.

<u>Sitting posture (A).</u>

Changes occur in thirty-three of the thirty-six cases. Twenty-five vertical hearts become still more vertical; six horizontal hearts become less horizontal; two horizontal hearts become vertical. The three cases showing no change comprise one vertical, one horizontal and one intermediate heart.

<u>Standing posture (B).</u>

Changes occur in thirty-three of the thirty-six cases. Twenty-five vertical hearts become still more vertical and one of them also shows evidence of clockwise rotation around the long axis; three horizontal hearts become less horizontal; five horizontal hearts become vertical and one of them shows evidence of backward rotation of the apex. The three cases showing no change are the same as those in posture A.

<u>45° head up posture (C).</u>

Changes occur in thirty-three of the thirty-six cases. Twenty-five vertical hearts become more vertical; three horizontal hearts become less horizontal; five horizontal hearts become vertical. The three cases showing no change are the same as those in postures A and B.

<u>45° head down posture (H).</u>

Changes occur in twenty of the twenty-three cases. Fifteen vertical hearts become less vertical; five horizontal hearts become more horizontal. Three vertical hearts show no change.

Right lateral posture (E).

Changes occur in thirty-three of the thirty-six cases. The changes fall into three groups.

(a) Three vertical hearts become horizontal; ten vertical hearts become less vertical and one of them shows evidence of backward rotation of the apex; five horizontal hearts become more horizontal and one of them shows evidence of backward rotation of the apex.

(b) One vertical and one horizontal heart show evidence of backward rotation of the apex alone.

(c) Ten vertical hearts become more vertical and three horizontal hearts become less horizontal.

The three cases showing no change comprise one vertical, one horizontal and one intermediate heart.

Left lateral posture (F).

Changes occur in all of the thirty-six cases. The changes fall into three groups.

(a) Twenty-two vertical hearts become more vertical and three of them also show evidence of forward rotation of the apex; eight horizontal hearts become less horizontal and one of them also shows evidence of forward rotation of the apex; one intermediate heart tends to become vertical and also shows evidence of forward rotation of the apex.

(b) One horizontal heart shows evidence of forward rotation of the apex alone.

(c) Four vertical hearts become less vertical.

Prone posture (G).

Changes occur in thirty-five of the thirty-six cases. The changes fall into two groups.

(a) Three vertical hearts become horizontal; nineteen vertical hearts become less vertical and one of them also shows evidence of forward rotation of the apex; nine horizontal hearts become more horizontal; one intermediate heart tends to become horizontal.

(b) Three vertical hearts show evidence of forward rotation of the apex alone.

The one case showing no change is a vertical heart.

P wave.

The control tracings (D) show that in aVR the P wave is inverted in all thirty-six cases. In aVL it is upright in twenty-three cases of which fifteen are vertical, seven are horizontal and one is intermediate; it is flat in five cases of which four are vertical and one horizontal; it is diphasic in one vertical heart; it is inverted in seven cases of which six are vertical and one is horizontal. In aVF it is upright in thirty-three cases, flat in two cases and diphasic in one case; the flat and diphasic P waves occur in vertical hearts.

Sitting posture (A).

Changes in the P waves occur in ten of the thirty-six cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVL and more positive in aVF in four cases. These comprise one vertical heart in which an upright P wave in aVL becomes inverted and a flat P wave in aVF becomes upright, one vertical heart in which an upright P wave in aVL becomes diphasic and a diphasic P wave in aVF becomes upright, one horizontal heart in which an upright P wave in aVL becomes inverted, and one horizontal heart in which an inverted P wave in aVL becomes more negative.

(2) The P wave becomes less positive in aVL in one case. This is a vertical heart in which an upright P wave in aVL becomes inverted.

(3) The P wave becomes more positive in aVF in five cases. These comprise four vertical hearts in one of which a flat P wave in aVF becomes upright, and one horizontal heart.

The twenty-six cases showing no change comprise nineteen vertical hearts, six horizontal hearts and one intermediate heart.

Changes in polarity of the P wave occur in five cases. In one case an upright P wave in aVL becomes inverted and a flat P wave in aVF becomes upright; in one case an upright P wave in aVL becomes diphasic and a diphasic P wave in aVF becomes upright; in two cases an upright P wave in aVL becomes inverted; and in one case a flat P wave in aVF becomes upright.

It is evident therefore that changes in the P waves are consistent.

<u>Standing posture (B).</u>

Changes in the P wave occur in twenty-four of the thirty-six cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVL and more positive in aVF in one case. This is a horizontal heart where an inverted P wave in aVR and aVL becomes more negative.

(2) The P wave becomes less positive in aVL and more positive in aVF in nine cases, of which six are vertical and three are horizontal hearts. The six vertical hearts comprise one case in which an upright P wave in aVL becomes inverted and a flat P wave in aVF becomes upright, one case in which an upright P wave in aVL becomes inverted and a diphasic P wave in aVF becomes upright, one case in which an upright P wave in aVL becomes inverted, one case in which an upright P wave in aVL becomes diphasic, one case in which a diphasic P wave in aVL becomes inverted and one case in which an inverted P wave in aVL becomes more negative. The three horizontal hearts comprise one case in which an upright P wave in aVL becomes inverted, one case in which an upright P wave in aVL becomes diphasic and one case in which a flat P wave in aVL becomes inverted.

(3) The P wave becomes less positive in aVL in two cases. They are both vertical hearts in which an upright P wave in aVL becomes flat.

(4) The P wave becomes more positive in aVF in twelve cases. These comprise eleven vertical hearts in one of which a flat P wave in aVF becomes upright and one horizontal heart.

The twelve cases showing no change comprise seven vertical hearts, four horizontal hearts and one intermediate heart. These cases also show no change in posture A.

Changes in polarity of the P wave occur in eleven cases. These comprise one case in which an upright P wave in aVL becomes inverted and a flat P wave in aVF becomes upright, one case in which an upright P wave in aVL becomes inverted and a diphasic P wave in aVF becomes upright, two cases in which an upright P wave in aVL becomes inverted, two cases in which an upright P wave in aVL becomes flat, two cases in which an upright P wave in aVL becomes diphasic, one case in which a flat P wave in aVL becomes inverted, one case in which a diphasic P wave in aVL becomes inverted, and one case in which a flat P wave in aVF becomes upright.

It is evident therefore that the changes in the P waves are consistent.

<u>45° head up posture (C)</u>.

Changes in the P waves occur in twenty-two of the thirty-six cases. The twenty-two cases are the same as those described in groups (1), (2) and (4) of the standing posture (B) and the individual changes in each case are identical. The two cases described in group (3) of posture B show no change in posture C.

45° head down posture (H).

Changes in the P wave occur in three of the twenty-three cases. In one vertical heart an inverted P wave in aVL becomes flat, in one vertical heart the P wave in aVF becomes less positive and in one horizontal heart the P wave in aVF becomes more positive.

Right lateral posture (E).

Changes in the P waves occur in eleven of the thirty-six cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and more positive in aVL in two vertical hearts. In one of these an inverted P wave in aVL becomes less negative.

(2) The P wave becomes less positive in aVR in three cases, one vertical, one horizontal and one intermediate heart.

(3) The P wave becomes more positive in aVL in one vertical heart. In this case an inverted P wave in aVL becomes less negative.

(4) The P wave becomes less positive in aVR and more positive in aVF in one horizontal heart.

(5) The P wave becomes more positive in aVL and aVF in one vertical heart. In this case a flat P wave in aVL becomes upright.

(6) The P wave becomes more positive in aVF in two vertical hearts.

(7) The P wave becomes more positive in aVR and less positive in aVL in one vertical heart. In this case an upright P wave in aVL becomes flat.

The twenty-five cases showing no change comprise eighteen vertical and seven horizontal hearts.

The changes are difficult to interpret and do not conform to any general pattern.

Left lateral posture (F).

Changes in the P waves occur in nine of the thirty-six cases. The types of change may be classified as follows.

(1) The P wave becomes more positive in aVR in three cases of which two are vertical hearts and one an intermediate heart.

(2) The P wave becomes less positive in aVL in three vertical hearts. In one of these an upright P wave becomes flat and in one a flat P wave becomes inverted.

(3) The P wave becomes more positive in aVF in two vertical hearts.

(4) The P wave becomes more positive in aVL in one vertical heart.

The twenty-seven cases showing no change comprise eighteen vertical and nine horizontal hearts.

The changes are too few and too variable to allow of any definite conclusions.

Prone posture (G).

Changes in the P waves occur in nine of the thirty-six cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVF and more positive in aVL in one vertical heart.

(2) The P wave becomes less positive in aVR in two cases, one vertical and one intermediate heart.

(3) The P wave becomes more positive in aVL in three cases, of which two are vertical hearts and one a horizontal heart. In one of the vertical hearts an inverted P wave in aVL becomes upright and in the other two cases inverted P waves in aVL become flat.

(4) The P wave becomes less positive in aVF in one horizontal heart.

(5) The P wave becomes less positive in aVL in one vertical heart.

(6) The P wave becomes more positive in aVF in one horizontal heart.

The twenty-seven cases showing no change comprise twenty vertical and seven horizontal hearts.

The changes are too few and too variable to allow of any definite conclusions.

T wave.

The control tracings (D) show that in aVR the T wave is inverted in all thirty-six cases. In aVL the T wave is upright in twenty-eight cases of which twenty are vertical hearts, seven are horizontal hearts and one is an intermediate heart; it is flat in two horizontal hearts; it is diphasic in one vertical heart; it is inverted in five vertical hearts. In aVF the T wave is upright in all thirty-six cases.

Sitting posture (A).

Changes in the T waves occur in twenty-nine of the thirty-six cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVL and less positive in aVF in nine cases of which eight are vertical hearts and one is a horizontal heart. In one of the vertical hearts a diphasic T wave in aVL becomes upright, in one an inverted T wave in aVL becomes flat, and in one an inverted T wave in aVL becomes less negative. In the horizontal heart a flat T wave in aVL becomes upright and an upright T wave in aVF becomes flat.

(2) The T wave becomes more positive in aVR and less positive in aVF in six cases of which two are vertical hearts and four are horizontal hearts. In one of the horizontal hearts an upright T wave in aVF becomes inverted.

(3) The T wave becomes more positive in aVL and less positive in aVF in eight cases of which seven are vertical hearts and one is a horizontal heart. In three of the vertical hearts an inverted T wave in aVL becomes flat.

(4) The T wave becomes less positive in aVF in one horizontal heart.

These four types of change are consistent.

(5) The T wave becomes more positive in aVR, aVL and aVF

in one vertical heart.

(6) The T wave becomes less positive in aVR and more positive in aVF in one vertical heart.

(7) The T wave becomes less positive in aVR in two vertical hearts.

(8) The T wave becomes less positive in aVL in one vertical heart.

The seven cases showing no change comprise four vertical hearts, two horizontal hearts and one intermediate heart.

Changes in polarity of the T wave occur in seven cases. In one case a flat T wave in aVL becomes upright and an upright T wave in aVF becomes flat, in four cases an inverted T wave in aVL becomes flat, in one case a diphasic T wave in aVL becomes upright, and in one case an upright T wave in aVF becomes inverted. These changes are all consistent.

Standing posture (B).

Changes in the T waves occur in all thirty-six cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVL and less positive in aVF in fifteen cases of which thirteen are vertical and two are horizontal hearts. The thirteen vertical hearts include one in which an inverted T wave in aVR becomes flat and an upright T wave in aVF becomes inverted, one in which an inverted T wave in aVL becomes upright, four in which an inverted T wave in aVL becomes

flat, one in which a diphasic T wave in aVL becomes upright and an upright T wave in aVF becomes inverted and three in which an upright T wave in aVF becomes inverted. In one of the horizontal hearts an inverted T wave in aVR becomes upright, a flat T wave in aVL becomes upright and an upright T wave in aVF becomes inverted; in the other an upright T wave in aVF becomes diphasic.

(2) The T wave becomes more positive in aVR and less positive in aVF in thirteen cases of which seven are vertical and six are horizontal hearts. In one of the vertical hearts an upright T wave in aVF becomes inverted. In two of the horizontal hearts an upright T wave in aVF becomes inverted and in another an upright T wave in aVF becomes flat.

(3) The T wave becomes more positive in aVL and less positive in aVF in one vertical heart.

(4) The T wave becomes less positive in aVF in two cases, one of which is a vertical and the other an intermediate heart.

These four types of change are consistent.

(5) The T wave becomes more positive in aVR and less positive in aVL and aVF in three vertical hearts. In one of these an upright T wave in aVF becomes inverted.

(6) The T wave becomes less positive in aVL in two cases, one of which is a vertical and the other a horizontal heart.

Changes in polarity of the T wave occur in seventeen cases. In one case an inverted T wave in aVR and a flat T wave in aVL become upright and an upright T wave in aVF becomes inverted, in one case an inverted T wave in aVR becomes flat and an upright T wave in aVF becomes inverted, in one case an inverted T wave in aVL becomes upright, in four cases an inverted T wave in aVL becomes flat, in one case a diphasic T wave in aVL becomes upright and an upright T wave in aVF becomes inverted, in seven cases an upright T wave in aVF becomes inverted, in one case an upright T wave in aVF becomes diphasic, and in one case an upright T wave in aVF becomes flat. These changes are all consistent.

<u>45° head up posture (C)</u>.

Changes in the T wave occur in thirty-five of the thirty-six cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVL and less positive in aVF in fourteen cases of which twelve are vertical and two are horizontal hearts. The twelve vertical hearts include one in which an inverted T wave in aVL becomes upright, three in which an inverted T wave in aVL becomes flat, one in which a diphasic T wave in aVL becomes upright, one in which an inverted T wave in aVL becomes less negative, one in which an upright T wave in aVF becomes inverted, and two in which an upright T wave in aVF becomes flat. In one of the horizontal

hearts an inverted T wave in aVR becomes flat, a flat T wave in aVL becomes upright and an upright T wave in aVF becomes inverted; in the other an upright T wave in aVF becomes diphasic.

(2) The T wave becomes more positive in aVR and less positive in aVF in fourteen cases of which eight are vertical and six are horizontal hearts. In one of the vertical hearts an upright T wave in aVF becomes flat. In one of the horizontal hearts an upright T wave in aVF becomes inverted and in another an upright T wave in aVF becomes flat.

(3) The T wave becomes more positive in aVL and less positive in aVF in two vertical hearts.

(4) The T wave becomes less positive in aVF in two cases, one of which is a vertical and the other an intermediate heart.

These four types of change are consistent.

(5) The T wave becomes more positive in aVR and less positive in aVL and aVF in two vertical hearts. In one of these an upright T wave in aVF becomes inverted.

(6) The T wave becomes less positive in aVL and aVF in one vertical heart.

The one case showing no change is a horizontal heart.

Changes in polarity of the T wave occur in fourteen cases. In one case an inverted T wave in aVR and a flat T wave in aVL become upright and an upright

T wave in aVF becomes inverted, in one case an inverted T wave in aVL becomes upright, in three cases an inverted T wave in aVL becomes flat, in one case a diphasic T wave in aVL becomes upright, in three cases an upright T wave in aVF becomes inverted, in one case an upright T wave in aVF becomes diphasic and in four cases an upright T wave in aVF becomes flat. These changes are all consistent.

It is evident that the changes in this posture are similar to those in posture B though they are less frequent and less obvious.

<u>45° head down posture (H)</u>.

Changes in the T waves occur in twenty-two of the twenty-three cases. The types of change may be classified as follows.

(1) The T wave becomes less positive in aVR and aVF and more positive in aVL in three vertical hearts.

(2) The T wave becomes less positive in aVR and more positive in aVL in two cases, one of which is a vertical and the other a horizontal heart.

(3) The T wave becomes more positive in aVL and less positive in aVF in four cases of which three are vertical hearts and one is a horizontal heart. In one of the vertical hearts an inverted T wave in aVL becomes flat.

(4) The T wave becomes less positive in aVR in one vertical heart.

(5) The T wave becomes more positive in aVL in five cases

of which four are vertical hearts and one is a horizontal heart. In one of the vertical hearts an inverted T wave in aVL becomes upright.

(6) The T wave becomes less positive in aVF in two vertical hearts.

These six types of change are consistent.

(7) The T wave becomes less positive in aVR and more positive in aVL and aVF in one horizontal heart.

(8) The T wave becomes more positive in aVL and aVF in one vertical heart. In this case an inverted T wave in aVL becomes upright.

(9) The T wave becomes more positive in aVF in two cases of which one is a vertical and the other a horizontal heart.

These three types of change are consistent.

(10) The T wave becomes more positive in aVR, aVL and aVF in one vertical heart.

The one case showing no change is a vertical heart.

Changes in polarity of the T wave occur in three cases; in two of them an inverted T wave in aVL becomes upright and in the third an inverted T wave in aVL becomes flat.

It is evident that the changes in the T wave in this posture fall into three groups.

(a) In seventeen cases the T wave tends to become less positive in aVR and aVF and more positive in aVL.

(b) In four cases the T wave tends to become less positive in aVR and more positive in aVL and aVF.

(c) In one case the T wave becomes more positive in aVR, aVL and aVF.

Right lateral posture (E).

Changes in the T waves occur in thirty-five of the thirty-six cases. The types of change may be classified as follows.

(1) The T wave becomes less positive in aVR and aVL and more positive in aVF in six cases of which five are vertical hearts and one is an intermediate heart. The five vertical hearts include one in which an upright T wave in aVL becomes inverted, one in which an upright T wave in aVL becomes diphasic and one in which an inverted T wave in aVL becomes more negative.

(2) The T wave becomes less positive in aVR and more positive in aVF in eight cases of which four are vertical and four are horizontal hearts.

(3) The T wave becomes less positive in aVL and more positive in aVF in nine cases of which six are vertical and three are horizontal hearts. The vertical hearts include one in which an upright T wave in aVL becomes inverted and one in which an upright T wave in aVL becomes flat. The horizontal hearts include one in which an upright T wave in aVL becomes flat and one in which a flat T wave in aVL becomes inverted.

(4) The T wave becomes less positive in aVR and aVL in two vertical hearts. In one of these an inverted T wave in aVL becomes more negative.

(5) The T wave becomes less positive in aVR in two vertical hearts.

(6) The T wave becomes less positive in aVL in two horizontal hearts. In one of these an upright T wave in aVL becomes flat.

These six types of change are consistent.

(7) The T wave becomes more positive in aVL and less positive in aVF in one vertical heart.

(8) The T wave becomes more positive in aVL in one vertical heart.

(9) The T wave becomes less positive in aVF in one vertical heart.

These three types of change are consistent.

(10) The T wave becomes less positive in aVR and more positive in aVL and aVF in one vertical heart.

(11) The T wave becomes more positive in aVR and aVF and less positive in aVL in two vertical hearts. In one of these an upright T wave in aVL becomes flat.

The one case showing no change is a vertical heart.

Changes in polarity of the T wave occur in eight cases. In two cases an upright T wave in aVL becomes inverted, in four cases an upright T wave in aVL becomes flat, in one case an upright T wave in aVL becomes diphasic and in one case a flat T wave in aVL becomes inverted. These changes are all consistent.

It is evident that the changes in the T wave in this posture fall into four groups.

(a) In twenty-nine cases the T wave tends to become less positive in aVR and aVL and more positive in aVF.

(b) In three cases the T wave tends to become more positive in aVL and less positive in aVF.

(c) In two cases the T wave becomes more positive in aVR and aVF and less positive in aVL.

(d) In one case the T wave becomes less positive in aVR and more positive in aVL and aVF.

Left lateral posture (F).

Changes in the T waves occur in thirty of the thirty-six cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVF and less positive in aVL in four cases of which three are vertical hearts and one is a horizontal heart. The vertical hearts include one in which an upright T wave in aVL becomes inverted. In the horizontal heart an upright T wave in aVL becomes flat.

(2) The T wave becomes more positive in aVR and less positive in aVL in five cases of which four are vertical hearts and one is an intermediate heart. The vertical hearts include one in which an upright T wave in aVL becomes inverted and one in which an upright T wave

in aVL becomes flat.

(3) The T wave becomes less positive in aVL and more positive in aVF in four cases of which one is a vertical heart and three are horizontal hearts. In the vertical heart an upright T wave in aVL becomes inverted. The horizontal hearts include one in which an upright T wave in aVL becomes flat and one in which a flat T wave in aVL becomes inverted.

(4) The T wave becomes more positive in aVR in two vertical hearts.

(5) The T wave becomes less positive in aVL in four cases of which three are vertical hearts and one is a horizontal heart. The vertical hearts include one in which an upright T wave in aVL becomes inverted and one in which an inverted T wave in aVL becomes more negative.

(6) The T wave becomes more positive in aVF in two vertical hearts.

(7) The T wave becomes more positive in aVR and aVF in one vertical heart.

These seven types of change are consistent.

(8) The T wave becomes more positive in aVR and less positive in aVL and aVF in three vertical hearts. In two of these an inverted T wave in aVL becomes more negative.

(9) The T wave becomes less positive in aVF in three cases of which two are vertical hearts and one is a horizontal heart.

These two types of change are consistent.

(10) The T wave becomes less positive in aVR and more positive in aVF in one vertical heart.

(11) The T wave becomes less positive in aVR in one vertical heart.

These two types of change are consistent.

The six cases showing no change comprise three vertical and three horizontal hearts.

Changes in polarity of the T wave occur in eight cases. In four cases an upright T wave in aVL becomes inverted, in three cases an upright T wave in aVL becomes flat, and in one case a flat T wave in aVL becomes inverted. These changes are all consistent.

It is evident that the changes in the T wave in this posture fall into three groups.

(a) In twenty-two cases there is a tendency for the T wave to become more positive in aVR and aVF and less positive in aVL.

(b) In six cases there is a tendency for the T wave to become more positive in aVR and less positive in aVL and aVF.

(c) In two cases there is a tendency for the T wave to become less positive in aVR and more positive in aVF.

Prone posture (G).

Changes in the T wave occur in thirty-three of the thirty-six cases. The types of change may be classified as follows.

(1) The T wave becomes less positive in aVR and aVF and more positive in aVL in three cases of which two are vertical hearts and one is a horizontal heart.

(2) The T wave becomes less positive in aVR and more positive in aVL in eight cases of which seven are vertical hearts and one is a horizontal heart. The vertical hearts include three cases in which an inverted T wave in aVL becomes flat.

(3) The T wave becomes more positive in aVL and less positive in aVF in four cases of which two are vertical and two are horizontal hearts.

(4) The T wave becomes less positive in aVR and aVF in two cases of which one is a vertical and the other an intermediate heart.

(5) The T wave becomes less positive in aVR in one vertical heart.

(6) The T wave becomes more positive in aVL in six cases of which four are vertical and two are horizontal hearts. The vertical hearts include one in which a diphasic T wave in aVL becomes upright and one in which an inverted T wave in aVL becomes less negative.

(7) The T wave becomes less positive in aVF in one vertical heart. In this case an upright T wave in aVF becomes inverted.

These seven types of change are consistent.

(8) The T wave becomes less positive in aVR and more positive in aVL and aVF in one vertical heart.

(9) The T wave becomes less positive in aVR and more positive in aVF in two cases of which one is a vertical and one a horizontal heart.

(10) The T wave becomes more positive in aVL and aVF in one vertical heart.

These three types of change are consistent.

(11) The T wave becomes more positive in aVR and less positive in aVL in one vertical heart.

(12) The T wave becomes less positive in aVL and more positive in aVF in one horizontal heart. In this case a flat T wave in aVL becomes inverted.

These two types of change are consistent.

(13) The T wave becomes more positive in aVR and aVL in two cases one of which is a vertical and the other a horizontal heart.

The three cases showing no change are all vertical hearts.

From this detailed analysis it is evident that the changes in the T wave in this posture fall into four groups.

(a) In twenty-five cases there is a tendency for the T wave to become less positive in aVR and aVF and more positive in aVL.

(b) In four cases there is a tendency for the T wave to become less positive in aVR and more positive in aVL and aVF.

(c) In two cases there is a tendency for the T wave to become more positive in aVR and aVF and less positive in aVL.

(d) In two cases the T wave becomes more positive in aVR and aVL.

SECTION 6.

The Effect of Posture on the Normal Electrocardiogram.

111. Precordial Leads.

In this section the effects of alteration of posture on the precordial leads in the thirty-six normal cases are described. For comparative purposes the appearances in the supine posture (D) are taken as the control. The changes are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The criteria for determining the position of the heart with regard to rotation around its long axis are the same as those already detailed in Part 111, Section 4. The changes encountered in some of the postures however could obviously not be explained by the effect of this type of rotation alone. It was finally considered that three other types of movement of the heart could be recognised.

(1) Lateral displacement of the heart: This is evident in the two lateral postures. The determining feature in assessing this type of movement is a uniform shift of the patterns in V1 to V3 or V4 to the right or left but with no evidence in V5 and V6 of an accompanying counter-clockwise or clockwise rotation respectively. In the case of a pure displacement to the right the size of the

deflections in V5 and V6 tends to diminish due to the increased distance of the electrodes from the heart but the reduction affects the amplitude of each wave proportionately and there is therefore no alteration in pattern. The reverse type of change in V5 and V6 should occur in a pure displacement to the left but in actual practice it is usually overshadowed by the second type of movement.

(2) Forward or backward displacement of the apex: Forward displacement or rotation of the apex is considered to occur in the left lateral and prone postures. In the left lateral posture there is almost invariably an increase in amplitude of the ventricular deflections in V4 to V6, the q, R and T waves being particularly affected. Furthermore, this is in most cases so conspicuous that the absolute size of these deflections is greater than the maximum comparable deflection in V4 to V6 in any of the other postures. There is also frequently evidence of change in pattern such as the appearance of a q wave or the disappearance of an s wave or the relative reduction in amplitude of an S wave. The final appearance in many cases is as if there has been clockwise rotation in positions V1 to V3 and counter-clockwise rotation in positions V4 to V6. The explanation for this is considered to be a displacement of the heart to the left with an accompanying forward displacement or rotation of the apex so that the surface of the left ventricle is in

closer proximity to positions V4, V5 and V6. In the prone posture changes of the kind described are also of fairly frequent occurrence in V4 to V6 but are usually less marked. In this posture however there is no evidence of alteration of V1 to V3. It is considered therefore that forward displacement or rotation of the apex has occurred alone. In the right lateral posture in some cases a considerable reduction in the amplitude of the ventricular deflections in V4 to V6 occurs without any indication in V1 to V3 of gross displacement to the right. In these cases it is considered that a backward displacement or rotation of the apex away from the anterior chest wall has occurred.

(3) An upward or downward movement of the heart as a whole so that it lies more "horizontally" or "vertically" respectively: The evidence for this is not very conclusive and is mainly based on the fact that in the 45° head down posture there is in many cases a tendency for the amplitude of the ventricular deflections in V4 to V6 to diminish without any other obvious change in pattern. This is considered to be due to an upward displacement of the heart causing it to lie more horizontally. In the sitting, standing and 45° head up postures in some cases there is also a tendency for the size of the deflections in V5 and V6 to diminish but this is usually accompanied by evidence of clockwise rotation. Setting aside the changes in the right and left lateral

and prone postures therefore, it would appear that in V4 to V6, the maximum deflections are registered in the supine posture. When an upward displacement of the heart such as may be produced by the 45° head down posture or a downward displacement of the heart such as may be produced by the standing, sitting or 45° head up posture occurs, the size of the deflections in V4 to V6 tends to diminish. This is presumably due to the movement of the main muscle mass of the heart away from these electrode positions in the one direction or the other.

With these considerations in mind the changes in the individual postures are now described.

The control tracings (D) show that moderate counter-clockwise rotation is present in eleven cases of which eight are vertical and three are horizontal hearts. Moderate clockwise rotation is present in nineteen cases of which fifteen are vertical and four are horizontal hearts. Marked clockwise rotation is present in six cases of which three are vertical hearts, two are horizontal hearts and one is an intermediate heart.

Sitting posture (A).

Clockwise rotation occurs in twenty-six cases of which eighteen are vertical and eight are horizontal hearts. Two of these vertical hearts also show evidence of becoming more vertical and one of the horizontal hearts shows evidence of becoming less horizontal.

One vertical heart shows evidence of becoming more vertical as its sole change.

The nine cases showing no change comprise seven vertical hearts, one horizontal heart and one intermediate heart.

A shift of the q wave to the left occurs in seven cases of which six are vertical hearts and one is a horizontal heart. Five of the vertical hearts show moderate clockwise rotation in the control and one of these is converted to marked clockwise rotation; the remaining one shows moderate counter-clockwise rotation in the control and this is converted to moderate clockwise rotation. The one horizontal heart shows moderate counter-clockwise rotation in the control and this is converted to moderate clockwise rotation.

Standing posture (B).

Clockwise rotation occurs in twenty-nine cases of which twenty-one are vertical and eight are horizontal hearts. Three of these vertical hearts also show evidence of becoming more vertical and two of the horizontal hearts show evidence of becoming less horizontal.

Four vertical hearts show evidence of becoming more vertical as their sole change.

One vertical heart shows evidence of becoming more vertical and also shows an anomalous shift of the q wave one position to the right from V5 to V4. The cause of this ~~is~~ obscure.

The two cases showing no change are one

intermediate and one horizontal heart.

A shift of the q wave to the left occurs in eight cases of which seven are vertical hearts and one is a horizontal heart. Three of the vertical hearts show moderate counter-clockwise rotation in the control and these are all converted to moderate clockwise rotation. The remaining four show moderate clockwise rotation in the control and two of these are converted to marked clockwise rotation. The one horizontal heart shows moderate counter-clockwise rotation in the control and this is converted to moderate clockwise rotation.

45° head up posture (C).

Clockwise rotation occurs in twenty-seven cases of which nineteen are vertical and eight are horizontal hearts. Two of these vertical hearts show evidence of becoming more vertical and two of the horizontal hearts show evidence of becoming less horizontal.

Three vertical hearts show evidence of becoming more vertical as their sole change.

One vertical heart shows evidence of becoming more vertical and also shows an anomalous shift of the q wave one position to the right from V5 to V4. This case shows the same change in the standing posture.

The five cases showing no change comprise three vertical hearts, one horizontal and one intermediate heart.

A shift of the q wave to the left occurs in seven cases of which six are vertical hearts and one is a horizontal heart. Three of the vertical hearts show moderate counter-clockwise rotation in the control and these are all converted to moderate clockwise rotation. The remaining three show moderate clockwise rotation in the control and two of these are converted to marked clockwise rotation. The one horizontal heart shows moderate counter-clockwise rotation in the control and this is converted to moderate clockwise rotation.

45° head down posture (H).

Counter-clockwise rotation occurs in eight cases of which six are vertical and two are horizontal hearts. Four of the vertical hearts also show evidence of becoming less vertical and one of the horizontal hearts becomes more horizontal. In one case a shift of the q wave to the right occurs converting a marked clockwise rotation to a moderate clockwise rotation.

Twelve cases, of which eleven are vertical hearts and one is a horizontal heart, show evidence of becoming more horizontal as their sole change.

One case shows evidence of becoming more horizontal and at the same time shows a shift of the q wave to the left from V4 to V5. This may be due to the more horizontal position of the heart as there is no other evidence of clockwise rotation.

The two cases showing no change are both horizontal hearts.

Right lateral posture (E).

All thirty-six cases show evidence of displacement of the heart to the right. Eleven cases show in addition evidence of some backward displacement of the apex.

A shift of the q wave occurs in eight cases in four of which it is to the right and in four to the left. The cases showing a shift to the right include three in which the shift is from V4 to V3 and this is obviously due to the lateral displacement of the heart. In the remaining case which shows marked clockwise rotation in the control, q waves appear in V5 and V6 in the right lateral posture. This can only be explained on the assumption that there has been counter-clockwise rotation.

The four cases showing a shift of the q wave to the left include one in which the shift is from V4 to V5 and two in which it is from V5 to V6; in the remaining case a q wave present in V6 in the control disappears in the right lateral posture. These four changes can be explained by a backward displacement or rotation of the apex.

Left lateral posture (F).

Thirty-four cases show evidence of displacement of the heart to the left. Twenty-seven of these also show evidence of forward rotation of the apex, two show evidence of forward rotation of the apex and counter-clockwise rotation and one shows evidence of counter-clockwise rotation.

One vertical heart shows evidence of forward rotation of the apex as its sole change.

One vertical heart shows evidence of counter-clockwise rotation as its sole change.

A shift of the q wave occurs in six cases. In four cases the shift is to the left from V4 to V5 and these are all obviously due to lateral displacement of the heart. In the remaining two the shift is to the right, one being from V6 to V5 and the other being the appearance of a q wave in V6 where it was absent in the control. These two changes can be explained by forward rotation of the apex.

Prone posture (G).

Changes occur in thirty-three of the thirty-six cases. Twenty cases show evidence of forward rotation of the apex, sixteen being vertical and four horizontal hearts. Five of the vertical hearts also show evidence of becoming less vertical and two of the horizontal hearts show evidence of becoming more horizontal.

Two vertical hearts show evidence of forward rotation of the apex and counter-clockwise rotation. In one of these showing marked clockwise rotation in the control, a q wave appears in V6.

Five cases of which three are vertical and two horizontal hearts show evidence of counter-clockwise rotation alone.

Four vertical hearts show evidence of becoming less vertical as their sole change.

One horizontal and one intermediate heart show evidence of becoming more horizontal as their sole change.

P wave.

No noteworthy changes occur in the P waves in any of the postures, apart from some increase in the P waves in V4 to V6 in a few cases in the sitting, standing and 45° head up postures.

T wave.

The control tracings (D) show that in all thirty-six cases the T waves in V2 to V6 are upright. In V1 the T wave is upright in twenty-four cases, flat in one case, diphasic in four cases and inverted in seven cases.

Sitting posture (A).

Changes in the T waves occur in twenty-two of the thirty-six cases.

The main change is a reduction in amplitude of the T waves particularly over the left side of the precordium. Thus the T wave becomes less positive in V1 to V6 in five cases, in V2 to V6 in two cases, inV4 to V6 in five cases, in V5 to V6 in five cases and in V6 alone in two cases; in one case the T wave becomes less positive in V1 alone and in two cases it becomes less positive in V1 to V4.

In four of these cases showing decrease of the T wave over the left precordium the T wave in V1 becomes more positive.

Standing posture (B).

Changes in the T wave occur in thirty-two of the thirty-six cases. Again the changes mainly consist in decrease of the T waves particularly over the left precordium. Thus the T wave becomes less positive in V1 to V6 in twelve cases, in V2 to V6 in seven cases, in V3 to V6 in four cases, in V4 to V6 in six cases, in V5 to V6 in two cases and in V6 alone in one case.

In seven of these cases showing decrease of the T wave over the left side of the precordium the T wave in V1 becomes more positive and in other two cases the T waves in V1 and V2 become more positive.

In one of the cases showing reduction of the T wave in all six leads, the T wave in V5 and V6 becomes flat.

45° head up posture (C).

Changes in the T waves occur in twenty-nine of the thirty-six cases and are similar to those in posture (B). Thus the T wave becomes less positive in V1 to V6 in twelve cases, in V2 to V6 in five cases, in V3 to V6 in three cases, in V4 to V6 in six cases, in V5 to V6 in two cases and in V6 alone in one case. In nine of those cases the changes are less marked than in posture (B) and in the other twenty they are the same as those in posture (B).

In six of the cases showing decrease of the T waves over the left side of the precordium the T wave in V1 becomes more positive and in one case the T waves in V1 and V2 become more positive.

45° head down posture (H).

Changes in the T wave occur in thirteen of the twenty-three cases. The individual leads affected vary considerably from case to case but the general tendency is for the T wave in V1 to V3 to become less positive and in V4 to V6 to become more positive. Only one exception occurs in a case where the T waves in V1 and V2 become more positive and the T wave in V6 becomes less positive.

In one case an inverted T wave in V1 becomes upright.

Right lateral posture (E).

Changes in the T wave occur in thirty-three of the thirty-six cases. The individual leads affected vary considerably from case to case but the general tendency is for the T waves in V1 and V2 or V1 to V3 to become more positive and for the T waves in V4 or V5 to V6 to become less positive. The T wave in V1 never becomes less positive and the T wave in V6 never becomes more positive.

Of the seven cases with inverted T waves in V1 in the control, two show upright T waves, one shows a flat T wave and four show less negative T waves in the right lateral posture. Three of the cases with diphasic T waves in V1 in the control have upright T waves in the right lateral posture.

Left lateral posture (F).

Changes in the T waves occur in all thirty-six cases. The individual leads affected vary considerably from case to case but the general tendency is for the T waves in V1 and V2 or V1 to V3 to become less positive and for the T waves in V3 or V4 to V6 to become more positive. The T wave in V1 never becomes more positive except in two cases where an inverted T wave in the control becomes slightly less negative. In both these cases the T wave in V2 becomes less positive and it seems likely that the apparently anomalous change in V1 is due to the lateral displacement so increasing the distance of the electrode from the heart that the absolute amplitude of the T wave is reduced. The T wave in V6 never becomes less positive.

In V1 eight cases with upright T waves in the control show inverted T waves in the left lateral posture; four cases with diphasic T waves in the control show inverted T waves in the left lateral posture; one case with flat T waves in the control shows inverted T waves in the left lateral posture and one case with an upright T wave in the control shows a flat T wave in the left lateral posture. Of the seven cases with inverted T waves in V1 in the control, four become more negative in the left lateral posture, one remains unaltered and two as described above become slightly less negative.

Prone posture (G).

Changes in the T waves occur in thirty of the thirty-six cases.

The individual leads affected vary considerably from case to case but the general tendency is for the T waves in V1 and V2 or V1 to V3 to become less positive and for the T waves in V3 or V4 to V6 to become more positive. Exceptions occur however in three cases. In one case the T wave becomes less positive in V1 to V6, in one case the T wave becomes less positive in V1 and V3 to V6 and in one case the T wave becomes less positive in V5 and V6.

The T wave in V1 never becomes more positive.

Three cases with upright T waves in V1 in the control show inverted T waves in the prone posture; one case with an upright T wave in the control shows a diphasic T wave in the prone posture and one case with a flat T wave in the control shows an inverted T wave in the prone posture. Of the seven cases with inverted T waves in V1 in the control, three show more negative T waves in the prone posture and four remain unaltered; of the four cases with diphasic T waves in V1 in the control, two show inverted T waves in the prone posture and two remain unaltered.

The changes in general therefore tend to resemble those in the left lateral posture but they are less frequent and less obvious.

SECTION 7.

The Effect of Posture on the Normal Electrocardiogram.

lV. Correlation of Standard Limb, Unipolar Limb and Precordial Leads.

In this section the individual changes which have been described in the three types of lead in the thirty-six normal cases are correlated.

Sitting posture (A).

In this posture the heart tends to undergo clockwise rotation around both its antero-posterior and long axes. Evidence of rotation around the antero-posterior axis is present in practically every case as shown by changes in the unipolar limb leads. In most cases there is also evidence of clockwise rotation around the long axis as judged by changes in the precordial leads. In a small number of cases, however, it would appear that rotation around one or other of these axes occurs alone.

The shift of the QRS axis to the right which is frequently seen in the standard leads is explained by the occurrence of these two types of rotation.

Changes in the P waves occur in about one third of the cases. The P wave tends to become more positive in aVF and less positive in aVL and these changes explain the increase in the P wave seen in standard leads ll and

111. The exact cause of these changes is unknown and the precordial leads throw no light on the problem.

Changes in the T wave are of frequent occurrence. The unipolar limb leads show that the tendency is for the T wave to become more positive in aVR and aVL and less positive in aVF. These changes explain the tendency for the T wave to become more positive in standard lead 1 and less positive in standard leads 11 and 111. Consideration of the precordial leads indicates that the decreased positivity of the T wave in aVF is due to a general decrease in positivity of the T wave over the antero-lateral ventricular surface. The increased positivity in aVR and aVL may also be due to this factor when these leads are facing the ventricular cavity.

<u>Standing posture (B)</u>.

In this posture the changes discussed under posture (A) become still more obvious. Thus in practically every case the unipolar limb leads show evidence of clockwise rotation around the antero-posterior axis and the precordial leads show evidence of clockwise rotation around the long axis. In a small number of cases rotation around one or other of these axes occurs alone. There is also evidence of a total downward displacement of the heart in many cases so that it comes to lie more vertically.

The shift of the QRS axis to the right in the standard leads is explained by the rotations around the antero-posterior and long axes either singly or in combination.

Changes in the P waves occur much more frequently than in posture (A) and are in fact present in two-thirds of the cases. The type of change is however exactly the same, the P wave becoming less positive in aVR and aVL and more positive in aVF. As before this explains the increase in the P waves seen in standard leads 11 and 111. Again the P wave in the precordial leads shows no significant change.

Changes in the T waves occur in every case. They are of the same type as occur in posture (A) but are much more obvious and lead to even more striking changes in the standard leads including several cases in which the T waves in leads 11 and 111 become inverted. The appearances in the unipolar limb leads again appear to be determined by the decreased positivity of the T waves in the precordial leads particularly over the antero-lateral aspect. In one case where the changes are particularly obvious the T waves in V5 and V6 actually become flat.

<u>45° head up posture (C)</u>.

The changes in this posture are very similar both in frequency and in type to the changes in posture (B). There is however a definite quantitative relationship in many cases between the changes in the two postures, so that some of the more striking changes seen in posture (B) are less obvious or even absent in posture (C). This finding may be of some importance in assessing the relative parts played by the two possible causative factors in the production of the electrocardiographic changes in the sitting, standing and 45° head up postures, namely, alteration in the position of the heart and autonomic nervous influences. The autonomic nervous influence is supposed to be due to diminished venous return in the vertical posture which results in sympathetic stimulation. The venous return is unlikely to be influenced to any great extent by change from the standing to the 45° head up posture. On the other hand such a change in posture causes the heart to become less vertical in most cases and also to undergo some counter-clockwise rotation.

<u>45° head down posture (H).</u>

In this posture the heart tends to undergo counter-clockwise rotation around both its antero-posterior and long axes. There is also evidence in many cases of a total upward displacement of the heart so that it comes to lie more horizontally. Of the twenty-three cases studied, fifteen show evidence of counter-clockwise rotation around the antero-posterior axis; seven show evidence of counter-clockwise rotation around both the antero-posterior and long axes; and one shows counter-clockwise rotation around the long axis alone.

The shift of the QRS axis to the left which is almost invariably seen in the standard leads is explained by the occurrence of these two types of rotation either singly or in combination.

Eighteen out of the twenty-three cases also show evidence of a total upward displacement of the heart as judged by changes in the precordial leads.

Changes in the P wave in this posture are infrequent and occur in only three cases. The P wave in aVL becomes more positive and in aVF less positive. These changes are the reverse of those which occur in postures A, B and C and are associated with decrease of the P wave in standard leads 11 and 111. The P wave in the precordial leads shows no change.

Changes in the T waves are of frequent occurrence. The unipolar limb leads show that the tendency in most cases is for the T wave to become less positive in aVR and aVF and more positive in aVL though in a few cases it becomes less positive in aVR and more positive in both aVL and aVF. These changes account for the increase of the T wave in standard lead 1 and the decrease in standard lead 111. In the precordial leads the T wave tends to become less positive in V1 to V3 and more positive in V4 to V6. The changes in V1 to V3 account for the increased negativity of the T wave in aVR. The increased positivity of the T wave in aVL is probably due to a combination of three factors, (1) the increased positivity of the T waves in V4 to V6, (2) the counter-clockwise rotation of the heart around its antero-posterior and long axes and (3) the total upward displacement of the ventricular mass of the heart. The final result is that the left ventricular mass faces more directly and is in closer proximity to the left arm and shoulder region which determines the potentials in aVL. These same factors in conjunction with the decreased positivity of the T waves in the V2 to V4 region cause the T wave in aVF to become less positive in most cases. Occasionally, however, where the amount of rotation and displacement is less, the increased positivity in the V4 to V6 region outweighs the decrease in the V2 to V4 region and the T wave in aVF becomes more positive.

Right lateral posture (E).

In this posture the changes in the three types of lead are difficult to correlate. Furthermore, the changes in the standard and unipolar limb leads are inconsistent. Thus from the unipolar limb leads it would appear that in eighteen cases counter-clockwise rotation around the antero-posterior axis occurs, in thirteen cases clockwise rotation around the antero-posterior axis occurs and in five cases there is no appreciable change. These findings are in approximate agreement with the appearances in the standard leads where twenty-five cases show a shift of the QRS axis to the left, six show a shift to the right and five show no change.

The precordial leads in all cases show evidence of displacement of the heart to the right and in about one-third of the cases there is also evidence of backward displacement or rotation of the apex. There is no evidence of counter-clockwise rotation around the long axis except perhaps in one case. On the other hand the cases showing backward rotation of the apex may also have some degree of clockwise rotation. No satisfactory explanation of the two apparently contradictory types of change in the standard and unipolar limb leads can be given. From the findings in the precordial leads, however, it seems justifiable to conclude that rotation around the long axis is not a major factor in the production of the changes in this posture.

Changes in the P wave occur in the standard and unipolar limb leads in rather less than one-third of the cases. These changes however are too slight and variable for any definite conclusion to be drawn. No significant changes occur in the precordial leads.

Changes in the T wave occur in the standard limb, unipolar limb and precordial leads in practically every case. Here again the changes are not constant.
In the majority of cases however the unipolar limb leads show that the T wave becomes less positive in aVR and aVL and more positive in aVF. This accounts for the two main types of change found in the standard leads, namely, an increase in the T waves in all three leads or a shift

of the axis of the T wave to the right. In a small group of cases however the T wave becomes more positive in aVL and less positive in aVF. This accounts for the third type of change found in the standard limb leads namely a shift of the axis of the T wave to the left. The precordial leads show a uniform tendency to increase in the T waves in V1 to V3 and decrease in the T waves in V4 to V6. This is in keeping with the displacement to the right but it is difficult to see how it can account for the common type of change in the T waves in the unipolar limb leads. One possible explanation is that the backward displacement of the apex may cause the increased positivity in the V1 to V3 region to be reflected in aVF and the decreased positivity in the V4 to V6 region to be reflected in aVL and aVR.

Left lateral posture (F).

In this posture the changes in the three types of lead are difficult to correlate though they are more consistent than in posture (E). Thus from the unipolar limb leads it would appear that in thirty-one cases clockwise rotation around the antero-posterior axis occurs, in four cases counter-clockwise rotation occurs and in one case there is no evidence of rotation. These findings are in fair agreement with the appearances in the standard limb leads where thirty-one cases show a shift of the QRS axis to the right, one case shows a shift to the left and four show no change.

The precordial leads show evidence of displacement of the heart to the left in thirty-four cases; in twenty-nine of these there is also evidence of forward rotation of the apex and in ____ other three there is evidence of counter-clockwise rotation around the long axis. Of the remaining two cases one has forward rotation of the apex alone and the other shows counter-clockwise rotation around the long axis alone. In no case is there any definite evidence of clockwise rotation around the long axis. It seems justifiable to conclude therefore that rotation around the long axis plays little or no part in the production of the changes in this posture.

Changes in the P wave occur in the standard and unipolar limb leads in about one quarter of the cases. These changes however are too slight and too variable for any definite conclusions to be drawn. No significant changes in the P waves occur in the precordial leads.

Changes in the T waves occur in thirty cases in the unipolar limb leads and in twenty-two cases in the standard limb leads. The changes fall into two main groups. In the majority of cases the T wave becomes more positive in aVR and aVF and less positive in aVL; this accounts for the common type of change found in the standard limb leads namely a shift of the axis of the T wave to the right. In a small group of cases the T wave becomes more positive in aVR and less positive in aVL and aVF; this accounts for the less frequent type of change found in the standard limb leads namely a shift of the axis of the T wave to the left. The precordial leads show a uniform tendency to decrease in the T waves in V1 to V3 and increase in the T waves in V4 or V5 to V6. This is partly due to displacement of the heart to the left and partly to forward rotation or displacement of the apex. The displacement of the heart to the left and increased positivity of the T wave in the V4 to V6 region would seem to account for the common increase in positivity of the T wave in aVF which now faces more directly the left ventricular mass and it also accounts for the decreased positivity of the T wave in aVL which now tends to face more towards the cavity of the ventricle. The increased positivity of aVR however is more difficult to explain. It is possible that the forward rotation of the apex may cause the increased positivity in V4 to V6 to be reflected in aVR but a more likely cause may be the increased distance between the left ventricular mass of the heart and the right arm attachment caused by the lateral displacement of the heart. This would tend to diminish the absolute amplitude of the T wave in aVR and render it apparently less negative. The decreased positivity in aVF found less frequently in this posture might be due to extreme forward displacement of the apex causing the left ventricular mass to turn away from this lead.

<u>Prone posture (G).</u>

In this posture the heart tends to undergo counter-clockwise rotation around its antero-posterior axis. Evidence of this change is present in the unipolar limb leads in thirty-two cases. In three other cases the unipolar limb leads show evidence of forward rotation of the apex and in one case they show no change. Changes are present in the precordial leads in all cases. Eighteen cases show forward rotation of the apex and an upward displacement of the heart, five cases show counter-clockwise rotation and an upward displacement of the heart, two cases show forward rotation of the apex, counter-clockwise rotation and upward displacement of the heart, two cases show forward rotation of the apex alone and nine cases show upward displacement of the heart alone. In this posture therefore the heart may undergo counter-clockwise rotation around both its antero-posterior and long axes in association with forward rotation of the apex. These changes may occur separately or in combination. The heart is also liable to a total upward displacement. The frequent shift of the QRS axis to the left in the standard leads is explained by the counter-clockwise rotation around the antero-posterior and long axes.

Changes in the P waves occur in about a quarter of the cases in the unipolar and standard limb leads. These changes however are too slight and too variable for any definite conclusions to be drawn.

Changes in the T waves occur in practically all cases in the three types of lead. In the unipolar limb leads in most cases the T wave becomes less positive in aVR and aVF and more positive in aVL; in a small number of cases however the T wave becomes less positive in aVR and more positive in both aVL and aVF. These two types of change account for the common alteration in the standard leads namely a shift of the axis of the T wave to the left. In two cases the T wave becomes more positive in aVR and aVF and less positive in aVL. This accounts for the shift of the axis of the T wave to the right which occurs in two cases in the standard leads. The precordial leads show a uniform tendency to decrease in the T waves in V1 to V3 and to increase in the T waves in V4 to V6. The changes in V1 to V3 account for the common increase in negativity of the T waves in aVR. The increased positivity of the T wave in aVL is probably due to a combination of three factors, (1) the increased positivity of the T waves in V4 to V6, (2) the counter-clockwise rotation of the heart around its antero-posterior and long axes and (3) the total upward displacement of the ventricular mass of the heart. These same factors usually cause the T wave in aVF to become less positive. The occasional occurrence of increased positivity in aVR may be due to extreme forward rotation of the apex.

In conclusion it is apparent that the electro-cardiographic changes in postures A, B, C, H and G can be interpreted fairly satisfactorily by the unipolar method. In the two lateral postures E and F however the changes are not consistent and discrepancies occur which are difficult to explain. It is just possible that the lateral displacement of the heart which occurs in these two postures so disturbs the electrical relationships within the body that the fundamental assumptions of the Einthoven equilateral triangle theory, upon which the unipolar theory depends, cease to be strictly valid.

SECTION 8.

The Effect of Posture on the Abnormal Electrocardiogram.

1. Standard Limb Leads.

In this section the effects of alteration of posture on the standard limb leads in twenty abnormal cases are described. For comparative purposes the appearances in the supine posture (D) are taken as the control. The changes are described under the three headings, QRS axis, P wave and T wave.

QRS axis.

The control tracings (D) show that five cases have right axis deviation, four cases have left axis deviation and eleven cases have no axis deviation.

In the sitting posture (A) sixteen cases show a shift of the QRS axis to the right though in five of them the shift is of relatively slight degree. Two cases show a slight shift of the QRS axis to the left. Two cases show no change.

In the standing posture (B) seventeen cases show a shift of the QRS axis to the right though in four of them the shift is of relatively slight degree. Two cases show a slight shift of the QRS axis to the left. One case shows no change.

In the 45° head up posture (C) sixteen cases show a shift of the QRS axis to the right though in six of them it is of relatively slight degree. Two cases show a slight shift of the QRS axis to the left. Two cases show no change.

In the right lateral posture (E) seventeen cases show a shift of the QRS axis to the left though in seven of them it is of relatively slight degree. Two cases show a shift of the QRS axis to the right, in one of them the shift being of relatively slight degree. One case shows no change.

In the left lateral posture (F) nineteen cases show a shift of the QRS axis to the right though in seven of them the shift is of relatively slight degree. One case shows a shift of the QRS axis to the left.

In the prone posture (G) eighteen cases show a shift of the QRS axis to the left though in eight of them the shift is of relatively slight degree. One case shows a shift of the QRS axis to the right. One case shows no change.

P wave.

The control tracings (D) show that sixteen cases have upright P waves in all three leads; two cases have upright P waves in leads 1 and 11 and diphasic P waves in lead 111; and one case has a flat P wave in lead 1 and upright P waves in leads 11 and 111. The remaining case is one of auricular fibrillation.

In the sitting posture (A) ten cases show no change in the P waves. Six cases show increase of the

P waves in leads 11 and 111. Two cases show increase of the P waves in all three leads. One case shows an increase of the P wave in lead 1 alone.

In the standing posture (B) thirteen cases show an increase of the P waves in leads 11 and 111. Six cases show no change.

In the 45° head up posture (C) the changes are very similar to those in the standing posture. Thus twelve cases show an increase of the P waves in leads 11 and 111 and these are included in the thirteen cases showing a similar change in the standing posture. Seven cases show no change.

In the right lateral posture (E) sixteen cases show no change in the P waves. The remaining three cases show a variety of changes. Thus in one case the P wave is increased in leads 1 and 11; in one case it is increased in leads 11 and 111; and in one case it is increased in lead 1 alone.

In the left lateral posture (F) fourteen cases show no change in the P waves. The remaining five cases show a variety of changes. Thus in two cases the P wave is diminished in leads 1 and 11; in one case it is diminished in lead 11 alone; in one case it is diminished in lead 1 and increased in leads 11 and 111; and in one case it is increased in leads 11 and 111.

In the prone posture (G) thirteen cases show no change in the P waves. The remaining six cases show a variety of changes. Thus in two cases the P wave is increased in leads 11 and 111; in two cases it is diminished in leads 11 and 111; in one case it is diminished in leads 1 and 11; and in one case it is diminished in lead 111 alone.

T wave.

The control tracings (D) show that ten cases have upright T waves in all three leads; one case has upright T waves in leads 1 and 11 and a flat T wave in lead 111; three cases have upright T waves in leads 1 and 11 and inverted T waves in lead 111; four cases have upright T waves in lead 1, diphasic T waves in lead 11 and inverted T waves in lead 111; one case has an upright T wave in lead 1 and inverted T waves in leads 11 and 111; one case has an inverted T wave in lead 1 and upright T waves in leads 11 and 111.

Sitting posture (A).

Changes in the T waves occur in fourteen of the twenty cases. The types of change may be classified as follows:

(1) The T wave becomes less positive in leads 11 and 111 in eleven cases. These include one case in which upright T waves in leads 11 and 111 become flat, one case in which an upright T wave in lead 11 becomes diphasic and a flat T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 11 becomes flat and an inverted T wave in lead 111

becomes more negative, one case in which a diphasic T wave in lead 11 becomes more negative and an inverted T wave in lead 111 becomes more negative and two cases in which inverted T waves in lead 111 become more negative.

(2) The T wave becomes more positive in lead 1 and less positive in lead 111 in three cases. These include one case in which an upright T wave in lead 111 becomes inverted and one case in which an inverted T wave in lead 111 becomes more negative.

From this detailed analysis it is evident that changes in the polarity of the T wave occur in four cases. These comprise one case in which upright T waves in leads 11 and 111 become flat, one case in which an upright T wave in lead 11 becomes diphasic and a flat T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 11 becomes flat, and one case in which an upright T wave in lead 111 becomes inverted. The changes in polarity are therefore all consistent.

It is also clear that in all fourteen cases there is a shift of the axis of the T wave to the left.

Standing posture (B).

Changes in the T waves occur in nineteen of the twenty cases. The types of change may be classified as follows:

(1) The T wave becomes less positive in leads 11 and 111 in thirteen cases. These include one case in which

an upright T wave in lead 11 becomes diphasic and a flat T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 11 becomes flat and an inverted T wave in lead 111 becomes more negative, one case in which an upright T wave in lead 11 becomes inverted and an inverted T wave in lead 111 becomes more negative, two cases in which diphasic T waves in lead 11 become more negative and inverted T waves in lead 111 become more negative, two cases in which upright T waves in lead 111 become diphasic, and one case in which an inverted T wave in lead 111 becomes more negative.

(2) The T wave becomes less positive in all leads in four cases. These include one case in which an upright T wave in lead 1 becomes flat, one case in which upright T waves in leads 11 and 111 become flat, and one case in which a diphasic T wave in lead 11 becomes inverted and an inverted T wave in lead 111 becomes more negative.

(3) The T wave becomes more positive in lead 1 and less positive in lead 111 in one case. In this case an inverted T wave in lead 111 becomes more negative.

(4) The T wave becomes less positive in leads 1 and 11 and more positive in lead 111 in one case. In this case inverted T waves in leads 11 and 111 become more negative in lead 11 and less negative in lead 111.

From this detailed analysis it is evident that changes in polarity of the T waves occur in eight cases. These comprise one case in which an upright T wave in lead 1 becomes flat, one case in which upright T waves in leads 11 and 111 become flat, one case in which an upright T wave in lead 11 becomes diphasic and a flat T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 11 becomes flat, one case in which an upright T wave in lead 11 becomes inverted, one case in which a diphasic T wave in lead 11 becomes inverted, and two cases in which upright T waves in lead 111 become diphasic.

It is also clear that the changes in the T waves fall into three groups. (a) In four cases the T wave becomes less positive in all leads. (b) In fourteen cases there is a shift of the axis of the T wave to the left. (c) In one case there is a shift of the axis of the T wave to the right.

<u>45° head up posture (C)</u>.

Changes in the T waves occur in fifteen of the twenty cases. The types of change may be classified as follows:

(1) The T wave becomes less positive in leads 11 and 111 in twelve cases. These include one case in which an upright T wave in lead 11 becomes diphasic and a flat T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 11 becomes flat and an inverted T wave in lead 111 becomes more negative,

one case in which a diphasic T wave in lead 11 becomes more negative and an inverted T wave in lead 111 becomes more negative, one case in which an upright T wave in lead 111 becomes diphasic, and one case in which an inverted T wave in lead 111 becomes more negative. Of the twelve cases in this group eleven show a similar type of change in the standing posture; the remaining case shows less positive T waves in all leads.

(2) The T wave becomes less positive in all leads in one case. In this case an upright T wave in lead 1 becomes flat. A similar type of change occurs in this case in the standing posture.

(3) The T wave becomes less positive in leads 1 and 11 in one case. In this case a diphasic T wave in lead 11 becomes more negative. In the standing posture this case shows less positive T waves in all leads.

(4) The T wave becomes less positive in leads 1 and 11 and more positive in lead 111 in one case. In this case inverted T waves in leads 11 and 111 become more negative in lead 11 and less negative in lead 111. A similar type of change occurs in this case in the standing posture.

From this detailed analysis it is evident that changes in polarity of the T waves occur in four cases. These comprise one case in which an upright T wave in lead 1 becomes flat, one case in which an upright T wave in lead 11 becomes diphasic and a flat T wave in lead 111 becomes inverted, one case in which an upright T wave in lead 11 becomes flat, and one case in which an upright T wave in lead 111 becomes diphasic. The changes are considerably less frequent and less marked than in the standing posture but are similar in type.

It is also clear that the changes in the T waves fall into three groups. (a) In one case the T waves are less positive in all leads. (b) In twelve cases there is a shift of the axis of the T wave to the left. (c) In two cases there is a shift of the axis of the T wave to the right.

Right lateral posture (E).

Changes in the T waves occur in fourteen of the twenty cases. The types of change may be classified as follows:

(1) The T wave becomes more positive in all leads in two cases. In one of these a flat T wave in lead 111 becomes upright.

(2) The T wave becomes more positive in leads 11 and 111 in seven cases. These include one case in which a diphasic T wave in lead 11 becomes upright and an inverted T wave in lead 111 becomes less negative, one case in which a diphasic T wave in lead 11 and an inverted T wave in lead 111 become less negative, and two cases in which inverted T waves in lead 111 become diphasic.

(3) The T wave becomes less positive in lead 1 and more positive in lead 111 in one case. In this case an inverted T wave in lead 111 becomes less negative.

(4) The T wave becomes more positive in leads 1 and 11 in one case.

(5) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in one case.

(6) The T wave becomes less positive in leads 11 and 111 in one case. In this case an upright T wave in lead 11 becomes flat and an inverted T wave in lead 111 becomes more negative.

(7) The T wave becomes less positive in all leads in one case.

From this detailed analysis it is evident that changes in polarity of the T waves occur in five cases. These comprise one case in which a diphasic T wave in lead 11 becomes upright, one case in which a flat T wave in lead 111 becomes upright, two cases in which inverted T waves in lead 111 become diphasic and one case in which an upright T wave in lead 11 becomes flat.

It is also clear that the changes in the T waves fall into four groups. (a) In two cases the T wave becomes more positive in all leads. (b) In one case the T wave becomes less positive in all leads. (c) In eight cases there is a shift of the axis of the T wave to the right. (d) In three cases there is a shift of the axis of the T wave to the left.

Left lateral posture (F).

Changes in the T waves occur in eleven of the twenty cases. The types of change may be classified as follows:

(1) The T wave becomes more positive in lead 1 and less positive in lead 111 in three cases. These include two cases in which inverted T waves in lead 111 become more negative.

(2) The T wave becomes less positive in leads 11 and 111 in three cases. In one of these a diphasic T wave in lead 11 and an inverted T wave in lead 111 become more negative.

(3) The T wave becomes more positive in leads 1 and 11 and less positive in lead 111 in one case. In this case an inverted T wave in lead 111 becomes more negative.

(4) The T wave becomes less positive in all leads in two cases. In one of these an upright T wave in lead 1 becomes inverted.

(5) The T wave becomes less positive in lead 1 and more positive in lead 111 in one case.

(6) The T wave becomes more positive in leads 11 and 111 in one case. In this case a diphasic T wave in lead 11 becomes upright and an inverted T wave in lead 111 becomes less negative.

From this detailed analysis it is evident that changes in polarity of the T waves occur in two cases.

In one of these an upright T wave in lead 1 becomes inverted and in the other a diphasic T wave in lead 11 becomes upright.

It is also clear that the changes in the T waves fall into three groups. (a) In two cases the T wave becomes less positive in all leads. (b) In seven cases there is a shift of the axis of the T wave to the left. (c) In two cases there is a shift of the axis of the T wave to the right.

Prone posture (G).

Changes in the T waves occur in seventeen of the twenty cases. The types of change may be classified as follows:

(1) The T wave becomes more positive in lead 1 and less positive in lead 111 in six cases. These include one case in which an upright T wave in lead 111 becomes flat, one case in which a flat T wave in lead 111 becomes inverted and two cases in which inverted T waves in lead 111 become more inverted.

(2) The T wave becomes more positive in leads 1 and 11 and less positive in lead 111 in three cases. These include one case in which a diphasic T wave in lead 11 becomes flat and an inverted T wave in lead 111 becomes more negative and one case in which an inverted T wave in lead 111 becomes more negative.

(3) The T wave becomes more positive in lead 1 and less positive in leads 11 and 111 in one case.

(4) The T wave becomes less positive in leads 11 and 111 in one case.

(5) The T wave becomes more positive in all leads in two cases.

(6) The T wave becomes less positive in all leads in one case. In this case an upright T wave in lead 1 becomes flat.

(7) The T wave becomes more positive in leads 11 and 111 in two cases. In one of these a diphasic T wave in lead 11 and an inverted T wave in lead 111 become less negative.

(8) The T wave becomes less positive in lead 1 and more positive in lead 111 in one case. In this case an inverted T wave in lead 111 becomes less negative.

From this detailed analysis it is evident that changes in polarity of the T waves occur in four cases. These comprise one case in which a diphasic T wave in lead 11 becomes flat, one case in which an upright T wave in lead 111 becomes flat, one case in which a flat T wave in lead 111 becomes inverted and one case in which an upright T wave in lead 1 becomes flat.

It is also clear that the changes in the T wave fall into four groups. (a) In eleven cases there is a shift of the axis of the T wave to the left. (b) In three cases there is a shift of the axis of the T wave to the right. (c) In two cases the T wave becomes more positive in all leads. (d) In one case the T wave becomes less positive in all leads.

SECTION 9.

The Effect of Posture on the Abnormal Electrocardiogram.

11. Unipolar Limb Leads.

In this section the effects of alteration of posture on the unipolar limb leads in the twenty abnormal cases are described. For comparative purposes the appearances in the supine posture (D) are taken as the control. The changes are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The criteria for determining the position of the heart are the same as those described in Part 111, Section 4.

The control tracings (D) show that in eleven cases the heart is vertical and in nine cases it is horizontal. Of the eleven vertical hearts, four show right axis deviation in the standard limb leads, six show no axis deviation and one shows left axis deviation. Of the nine horizontal hearts, three show left axis deviation, five show no axis deviation and one shows right axis deviation.

Sitting posture (A)

Changes occur in fifteen of the twenty cases. Nine vertical hearts become more vertical and three of them also show evidence of clockwise rotation around the long axis; six horizontal hearts become less horizontal. The five cases showing no change comprise two vertical and three horizontal hearts.

Standing posture (B).

Changes occur in nineteen of the twenty cases. Eleven vertical hearts become more vertical; six horizontal hearts become less horizontal; two horizontal hearts become vertical. The one case showing no change is a horizontal heart, and also shows no change in posture A.

45° head up posture (C).

Changes occur in seventeen of the twenty cases. Ten vertical hearts become more vertical and three of them also show evidence of clockwise rotation around the long axis; five horizontal hearts become less horizontal; two horizontal hearts become vertical and these two hearts show the same change in posture B. The three cases showing no change comprise one vertical heart and two horizontal hearts and they also show no change in posture A.

Right lateral posture (E).

Changes occur in eighteen of the twenty cases. The changes fall into three groups.

(a) One vertical heart becomes horizontal; four vertical hearts become less vertical and one of them also shows evidence of backward rotation of the apex; six horizontal hearts become more horizontal and three of them also show evidence of backward rotation of the apex.

(b) One horizontal and two vertical hearts show evidence of backward rotation of the apex alone.

(c) Four vertical hearts become more vertical and one of them also shows evidence of backward rotation of the apex. The two cases showing no change are both horizontal hearts.

Left lateral posture (F).

Changes occur in seventeen of the twenty cases. The changes fall into three groups.

(a) Seven vertical hearts become more vertical and two of them also show evidence of forward rotation of the apex; three horizontal hearts become less horizontal and two of them also show evidence of forward rotation of the apex.

(b) Two vertical and four horizontal hearts show evidence of forward rotation of the apex alone.

(c) One horizontal heart becomes more horizontal.

The three cases showing no change comprise two vertical hearts and one horizontal heart.

Prone posture (G).

Changes occur in sixteen of the twenty cases. The changes fall into two groups.

(a) One vertical heart becomes horizontal; seven vertical hearts become less vertical and two of them also show evidence of forward rotation of the apex; seven horizontal hearts become more horizontal and two of them also show evidence of forward rotation of the apex.

(b) One vertical heart shows evidence of forward rotation of the apex alone.

The four cases showing no change comprise two vertical and two horizontal hearts.

P wave.

Only ninteeen of the twenty cases are available for this analysis as the remaining case is one of auricular fibrillation.

The control tracings (D) show that in aVR the P wave is inverted in all nineteen cases. In aVL it is upright in five cases of which three are vertical and two are horizontal; it is flat in five cases of which three are vertical and two are horizontal; it is inverted in nine cases of which five are vertical and four are horizontal. In aVF it is upright in all nineteen cases.

Sitting posture (A).

Changes in the P wave occur in seven of the nineteen cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVL and more positive in aVF in three cases of which two are vertical hearts and one a horizontal heart. In these three cases inverted P waves in aVL become more negative.

(2) The P wave becomes less positive in aVL and more positive in aVF in two vertical hearts. In one of these an upright P wave in aVL becomes inverted and in the other a flat P wave in aVL becomes inverted.

(3) The P wave becomes less positive in aVL in one horizontal heart. In this case an upright P wave in aVL becomes inverted.

(4) The P wave becomes more positive in aVF in one

vertical heart.

The twelve cases showing no change comprise six vertical and six horizontal hearts.

Changes in polarity of the P wave occur in three cases, two in which upright P waves in aVL become inverted and one in which a flat P wave in aVL becomes inverted.

It is evident that the changes in the P waves are consistent.

Standing posture (B).

Changes in the P waves occur in thirteen of the nineteen cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVL and more positive in aVF in five cases of which three are vertical and two are horizontal hearts. In one of the vertical hearts a flat P wave in aVL becomes inverted and in the other two, inverted P waves in aVL become more negative. In one of the horizontal hearts an upright P wave in aVL becomes inverted and in the other an inverted P wave in aVL becomes more negative.

(2) The P wave becomes less positive in aVL and more positive in aVF in three cases of which two are vertical hearts and one a horizontal heart. In one of the vertical hearts an upright P wave in aVL becomes inverted; in the other two cases flat P waves in aVL become inverted.

(3) The P wave becomes less positive in aVR and more positive in aVF in two horizontal hearts.

(4) The P wave becomes more positive in aVF in three cases of which two are vertical hearts and one is a horizontal heart.

The six cases showing no change comprise four vertical and two horizontal hearts and these also show no change in posture A.

Changes in polarity of the P waves occur in five cases. In two of them upright P waves in aVL become inverted and in the other three, flat P waves in aVL become inverted.

It is evident that the changes in the P waves are consistent.

45° head up posture (C).

Changes in the P waves occur in thirteen of the nineteen cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVL and more positive in aVF in four cases of which two are vertical and two horizontal hearts. In one of the vertical hearts a flat P wave in aVL becomes inverted and in the other an inverted P wave in aVL becomes more negative. In one of the horizontal hearts an upright P wave in aVL becomes inverted and in the other an inverted P wave in aVL becomes more negative.

(2) The P wave becomes less positive in aVL and more positive in aVF in three cases of which two are vertical hearts and one a horizontal heart. In one of the vertical

hearts an upright P wave in aVL becomes flat; in the other two cases flat P waves in aVL become inverted.

(3) The P wave becomes less positive in aVR and more positive in aVF in two horizontal hearts.

(4) The P wave becomes less positive in aVR and aVL in one vertical heart. In this case an inverted P wave in aVL becomes more negative.

(5) The P wave becomes more positive in aVF in three cases of which two are vertical hearts and one is a horizontal heart.

The six cases showing no change are the same as those in posture B.

Changes in polarity of the P waves occur in the same five cases as in posture B and are of the same type.

It is evident that the changes in the P wave are consistent and are very similar to those in posture B.

Right lateral posture (E).

Changes in the P waves occur in thirteen of the nineteen cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVL and more positive in aVF in one vertical heart. In this case an inverted P wave in aVL becomes more negative.

(2) The P wave becomes less positive in aVR and more positive in aVF in four cases of which three are vertical hearts and one is a horizontal heart.

(3) The P waves become less positive in aVR in six cases of which two are vertical and four are horizontal hearts.

(4) The P wave becomes less positive in aVL in one vertical heart. In this case an inverted P wave in aVL becomes more negative.

(5) The P wave becomes less positive in aVF in one horizontal heart.

The six cases showing no change comprise four vertical and two horizontal hearts.

Apart from the one case in type (5) the changes in the P wave are consistent.

Left lateral posture (F).

Changes in the P waves occur in five of the nineteen cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR in one vertical heart.

(2) The P wave becomes more positive in aVL in one horizontal heart. In this case an inverted P wave in aVL becomes upright.

(3) The P wave becomes more positive in aVF in one horizontal heart.

(4) The P wave becomes less positive in aVF in two cases of which one is a vertical and one a horizontal heart.

The fourteen cases showing no change comprise nine vertical and five horizontal hearts.

The changes are too few and too variable to allow of any definite conclusions.

Prone posture (G).

Changes in the P waves occur in five of the nineteen cases. The types of change may be classified as follows.

(1) The P wave becomes less positive in aVR and aVF and more positive in aVL in one horizontal heart. In this case an inverted P wave in aVL becomes flat.

(2) The P wave becomes less positive in aVR and more positive in aVL in one horizontal heart. In this case an inverted P wave in aVL becomes flat.

(3) The P wave becomes more positive in aVL in one horizontal heart. In this case a flat P wave in aVL becomes upright.

(4) The P wave becomes less positive in aVF in one vertical heart.

(5) The P wave becomes more positive in aVR in one horizontal heart.

The fourteen cases showing no change comprise ten vertical and four horizontal hearts.

The changes are too few and too variable to allow of any definite conclusions, though apart from type (5) they are consistent.

T wave.

The control tracings (D) show that in aVR the T wave is inverted in nineteen cases of which eleven are vertical and eight are horizontal hearts; it is diphasic in one horizontal heart. In aVL the T wave is upright in nine cases of which five are vertical and four are horizontal hearts; it is flat in two vertical hearts; it is diphasic in one horizontal heart; it is inverted in eight cases of which four are vertical and four are horizontal hearts. In aVF the T wave is upright in twelve cases of which six are vertical and six are horizontal hearts; it is flat in one horizontal heart; it is diphasic in three cases of which two are vertical hearts and one is a horizontal heart; it is inverted in four cases of which three are vertical hearts and one is a horizontal heart.

Sitting posture (A).

Changes in the T waves occur in sixteen of the twenty cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVL and less positive in aVF in six cases of which four are vertical hearts and two are horizontal. The four vertical hearts comprise one in which an inverted T wave in aVR becomes flat and a diphasic wave in aVF becomes more negative, one in which a flat T wave in aVL becomes upright and an upright T wave in aVF becomes diphasic, one case in which an inverted T wave in aVL becomes upright, and one case in which an inverted T wave in aVL becomes flat. In one of the horizontal hearts an inverted T wave in aVL becomes upright and in the other a flat T wave in aVF becomes inverted.

(2) The T wave becomes more positive in aVR and less positive in aVF in one horizontal heart. In this case an upright T wave in aVF becomes inverted.

(3) The T wave becomes more positive in aVL and less positive in aVF in five cases of which three are vertical hearts and two are horizontal. In one of the vertical hearts an inverted T wave in aVL becomes less negative, in one a diphasic T wave in aVF becomes inverted and in one an inverted T wave in aVF becomes more negative. In one of the horizontal hearts an inverted T wave in aVL becomes less negative.

(4) The T wave becomes more positive in aVR in one vertical heart.

(5) The T wave becomes more positive in aVL in one vertical heart. In this case a flat T wave in aVL becomes upright.

These five types of change are consistent.

(6) The T wave becomes more positive in aVR and aVF and less positive in aVL in one vertical heart. In this case an inverted T wave in aVR becomes upright and an inverted T wave in aVF becomes less negative.

(7) The T wave becomes less positive in aVR and aVL and more positive in aVF in one horizontal heart. In this case an inverted T wave in aVL becomes more negative.

The four cases showing no change comprise one vertical heart and three horizontal hearts.

Changes in polarity of the T waves occur in ten cases. In one case an inverted T wave in aVR becomes upright, in one case an inverted T wave in aVR becomes flat, in two cases an inverted T wave in aVL becomes upright, in one case an inverted T wave in aVL becomes flat, in one case a flat T wave in aVL becomes upright, in one case a flat T wave in aVL becomes upright and an upright T wave in aVF becomes diphasic, in one case an upright T wave in aVF becomes inverted, in one case a flat T wave in aVF becomes inverted, and in one case a diphasic T wave in aVF becomes inverted. These changes are all consistent.

Standing posture (B).

Changes in the T waves occur in eighteen of the twenty cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVL and less positive in aVF in nine cases of which four are vertical and five are horizontal hearts. The four vertical hearts comprise one in which an inverted T wave in aVR becomes flat and a diphasic T wave in aVF becomes more negative, one in which an inverted T wave in aVL becomes flat, one in which an inverted T wave in aVL becomes less negative, and one in which an inverted T wave in aVF becomes more negative. The five horizontal hearts include one in which an inverted T wave in aVR becomes flat and an upright T wave in aVF becomes inverted, one in which an inverted T wave in aVR becomes flat and a flat T wave in

aVF becomes inverted, one in which an inverted T wave in aVL becomes flat and one in which an inverted T wave in aVL becomes less negative.

(2) The T wave becomes more positive in aVR and less positive in aVF in three vertical hearts. In one of these an inverted T wave in aVR becomes diphasic and an upright T wave in aVF becomes diphasic and in one an inverted T wave in aVF becomes more negative.

(3) The T wave becomes more positive in aVL and less positive in aVF in three cases of which two are vertical hearts and one is a horizontal heart. In one of the vertical hearts an inverted T wave in aVL becomes upright and in the other a diphasic T wave in aVF becomes inverted. In the horizontal heart an inverted T wave in aVL becomes less negative.

(4) The T wave becomes less positive in aVF in one horizontal heart. In this case an inverted T wave in aVF becomes more negative.

These four types of change are consistent.

(5) The T wave becomes more positive in aVR and aVF and less positive in aVL in one vertical heart. In this case an inverted T wave in aVR becomes upright and an inverted T wave in aVF becomes less negative.

(6) The T wave becomes less positive in aVR and aVL and more positive in aVF in one horizontal heart. In this case an inverted T wave in aVL becomes more negative.

The two cases showing no change are one vertical and one horizontal heart and they also show no change in posture A.

Changes in polarity of the T wave occur in nine cases. In one case an inverted T wave in aVR becomes upright, in one case an inverted T wave in aVR becomes flat, in one case an inverted T wave in aVR becomes flat and an upright T wave in aVF becomes inverted, in one case an inverted T wave in aVR becomes flat and a flat T wave in aVF becomes inverted, in one case an inverted T wave in aVR becomes diphasic and an upright T wave in aVF becomes diphasic, in one case an inverted T wave in aVL becomes upright, in two cases an inverted T wave in aVL becomes flat and in one case a diphasic T wave in aVF becomes inverted. These changes are all consistent.

<u>45° head up posture (C)</u>.

Changes in the T waves occur in eighteen of the twenty cases. The types of change may be classified as follows.

(1) The T wave becomes more positive in aVR and aVL and less positive in aVF in seven cases of which four are vertical hearts and three are horizontal. The four vertical hearts comprise one in which an inverted T wave in aVR becomes flat and a diphasic T wave in aVF becomes more negative, one in which an inverted T wave in aVL becomes flat, one in which an inverted T wave in aVL becomes less negative, and one in which an inverted T wave in aVF becomes more negative. In one of the horizontal

hearts an inverted T wave in aVR becomes flat and a flat T wave in aVF becomes inverted and in another an inverted T wave in aVL becomes less negative.

(2) The T wave becomes more positive in aVR and less positive in aVF in five cases of which three are vertical hearts and two are horizontal. In one of the vertical hearts an inverted T wave in aVR becomes upright and an inverted T wave in aVF becomes more negative, in another an inverted T wave in aVR becomes diphasic and an upright T wave in aVF becomes diphasic.

(3) The T wave becomes more positive in aVL and less positive in aVF in three cases of which two are vertical hearts and one is a horizontal heart. In one of the vertical hearts an inverted T wave in aVL becomes upright and in the other a diphasic T wave in aVF becomes inverted. In the horizontal heart an inverted T wave in aVL becomes less negative.

(4) The T wave becomes more positive in aVR in one horizontal heart.

These four types of change are consistent.

(5) The T wave becomes more positive in aVR and aVF and less positive in aVL in one vertical heart. In this case an inverted T wave in aVR becomes upright and an inverted T wave in aVF becomes less negative. A similar type of change occurs in this case in postures A and B.

(6) The T wave becomes less positive in aVR and aVL and more positive in aVF in one horizontal heart. In this

case an inverted T wave in aVL becomes more negative. The same type of change occurs in this case in postures A and B.

The two cases showing no change comprise one vertical and one horizontal heart and they also show no change in postures A and B.

Changes in polarity of the T wave occur in eight cases. In two cases an inverted T wave in aVR becomes upright, in one case an inverted T wave in aVR becomes flat, in one case an inverted T wave in aVR becomes flat and a flat T wave in aVF becomes inverted, in one case an inverted T wave in aVR becomes diphasic and an upright T wave in aVF becomes diphasic, in one case an inverted T wave in aVL becomes upright, in one case an inverted T wave in aVL becomes flat and in one case a diphasic T wave in aVF becomes inverted. These changes are all consistent.

It is evident that the changes in this posture are similar to those in posture B though they are less frequent and less obvious.

Right lateral posture (E).

Changes in the T waves occur in fourteen of the twenty cases. The types of change are classified as follows.

(1) The T wave becomes less positive in aVR and aVL and more positive in aVF in six cases of which three are vertical and three are horizontal hearts. In one of the

vertical hearts an upright T wave in aVL becomes flat and a diphasic T wave in aVF becomes upright, in the other two cases an inverted T wave in aVL becomes more negative. In one of the horizontal hearts an upright T wave in aVL becomes flat and a flat T wave in aVF becomes upright, in one an upright T wave in aVL becomes flat, and in one an inverted T wave in aVL becomes more negative.

(2) The T wave becomes less positive in aVR and more positive in aVF in three cases of which two are vertical hearts and one is a horizontal heart. In one of the vertical hearts a diphasic T wave in aVF becomes more positive.

(3) The T wave becomes less positive in aVL and more positive in aVF in one vertical heart. In this case an inverted T wave in aVF becomes less negative.

These three types of change are consistent.

(4) The T wave becomes less positive in aVR and aVF in one horizontal heart. In this case an inverted T wave in aVF becomes more negative.

(5) The T wave becomes more positive in aVL and less positive in aVF in one vertical heart. In this case an inverted T wave in aVL becomes less negative.

(6) The T wave becomes more positive in aVL in one horizontal heart. In this case an inverted T wave in aVL becomes flat.

These three types of change are consistent.

(7) The T wave becomes less positive in aVR and more positive in aVL and aVF in one vertical heart. In this case an inverted T wave in aVF becomes flat.

The six cases showing no change comprise three vertical and three horizontal hearts.

From this detailed analysis it is evident that the changes in the T wave fall into three groups.

(a) In ten cases there is a tendency for the T wave to become less positive in aVR and aVL and more positive in aVF.

(b) In three cases there is a tendency for the T wave to become less positive in aVR and aVF and more positive in aVL.

(c) In one case the T wave becomes less positive in aVR and more positive in aVL and aVF.

<u>Left lateral posture (F)</u>

Changes in the T waves occur in fifteen of the twenty cases. The types of change may be classified as follows.

(1) The T wave becomes less positive in aVR and aVF and more positive in aVL in one horizontal heart. In this case an inverted T wave in aVL becomes upright.

(2) The T wave becomes more positive in aVL and less positive in aVF in six cases of which four are vertical hearts and two are horizontal. In one of the vertical hearts a flat T wave in aVL becomes upright, in one a diphasic T wave in aVF becomes inverted and in two an

inverted T wave in aVF becomes more negative. In one of the horizontal hearts a diphasic T wave in aVL becomes more positive and a diphasic T wave in aVF becomes more negative, and in the other an inverted T wave in aVL becomes less negative.

(3) The T wave becomes more positive in aVL in one vertical heart.

(4) The T wave becomes less positive in aVR in one horizontal heart.

These four types of change are consistent.

(5) The T wave becomes more positive in aVR and less positive in aVL and aVF in one vertical heart. In this case an inverted T wave in aVL becomes more negative.

(6) The T wave becomes more positive in aVR and less positive in aVF in one horizontal heart.

(7) The T wave becomes less positive in aVL in two horizontal hearts. In one of these an upright T wave in aVL becomes flat and in the other an inverted T wave in aVL becomes more negative.

These three types of change are consistent.

(8) The T wave becomes less positive in aVR and more positive in aVL and aVF in one horizontal heart.

(9) The T wave becomes less positive in aVR and more positive in aVF in one vertical heart.

These two types of change are consistent.

The five cases showing no change comprise four vertical hearts and one horizontal heart.

From this detailed analysis it is evident that the changes in the T wave fall into three groups.

(a) In nine cases there is a tendency for the T wave to become less positive in aVR and aVF and more positive in aVL.

(b) In four cases there is a tendency for the T wave to become more positive in aVR and less positive in aVL and aVF.

(c) In two cases there is a tendency for the T wave to become less positive in aVR and more positive in aVL and aVF.

Prone posture (G).

Changes occur in the T waves in thirteen of the twenty cases. The types of change may be classified as follows.

(1) The T wave becomes less positive in aVR and aVF and more positive in aVL in one horizontal heart. In this case an inverted T wave in aVL becomes upright.

(2) The T wave becomes less positive in aVR and more positive in aVL in five cases of which two are vertical hearts and three are horizontal. In one of the vertical hearts a flat T wave in aVL becomes upright and in another an inverted T wave in aVL becomes less negative. In one of the horizontal hearts an inverted T wave in aVL becomes less negative.

(3) The T wave becomes more positive in aVL and less positive in aVF in two vertical hearts. In one of these a diphasic T wave in aVF becomes inverted and in the other

an inverted T wave in aVF becomes more inverted.

(4) The T wave becomes more positive in aVL in one vertical heart.

These four types of change are consistent.

(5) The T wave becomes less positive in aVR and more positive in aVL and aVF in one horizontal heart.

(6) The T wave becomes less positive in aVR and more positive in aVF in one vertical heart.

These two types of change are consistent.

(7) The T wave becomes less positive in aVL and more positive in aVF in one horizontal heart. In this case an inverted T wave in aVL becomes more negative.

(8) The T wave becomes more positive in aVR and aVL and less positive in aVF in one horizontal heart. In this case a flat T wave in aVF becomes diphasic.

The seven cases showing no change comprise five vertical and two horizontal hearts.

From this detailed analysis it is evident that the changes in the T wave fall into four groups.

(a) In nine cases there is a tendency for the T wave to become less positive in aVR and aVF and more positive in aVL.

(b) In two cases there is a tendency for the T wave to become less positive in aVR and more positive in aVL and aVF.

(c) In one case the T wave becomes less positive in aVL and more positive in aVF.

(d) In one case the T wave becomes more positive in aVR and aVL and less positive in aVF.

SECTION 10.

The Effect of Posture on the Abnormal Electrocardiogram.

111. Precordial Leads.

In this section the effects of alteration of posture on the precordial leads in the twenty abnormal cases are described. For comparative purposes the appearances in the supine posture (D) are taken as the control. The changes are described under the three headings, position of the heart, P wave and T wave.

Position of the heart.

The criteria for determining changes in the position of the heart are the same as those already detailed in Section 6.

The control tracings (D) show that moderate counter-clockwise rotation is present in one horizontal heart. Moderate clockwise rotation is present in eight cases of which three are vertical and five are horizontal hearts. Marked clockwise rotation is present in eleven cases of which eight are vertical and three are horizontal hearts.

Sitting posture (A).

Changes occur in all twenty cases.

Clockwise rotation occurs in sixteen cases of which eight are vertical and eight are horizontal hearts. One of these vertical hearts also shows evidence of becoming more vertical and four of the horizontal hearts show evidence of becoming less horizontal.

Two vertical hearts show evidence of becoming more vertical as their sole change.

One horizontal heart shows evidence of becoming less horizontal as its sole change.

One vertical heart with marked clockwise rotation shows evidence of becoming more vertical and at the same time a q wave appears in V6. The explanation for this is obscure.

Standing posture (B).

Changes occur in all twenty cases.

Nineteen cases show evidence of clockwise rotation. These comprise ten vertical hearts of which six also show evidence of becoming more vertical and nine horizontal hearts of which four show evidence of becoming less horizontal. One of the horizontal hearts with moderate clockwise rotation in the control shows a shift of the q wave to the left and is converted to marked clockwise rotation.

One vertieal heart with marked clockwise rotation shows evidence of becoming more vertical and at the same time a q wave appears in V6. This case shows the same change in posture (A).

45° head up posture (C).

The changes are identical with those in posture (B).

Right lateral posture (E).

Changes occur in nineteen of the twenty cases.

Eighteen cases show evidence of displacement of the heart to the right. In addition five cases of which three are vertical and two are horizontal show evidence of backward rotation of the apex and two cases of which one is a vertical and the other a horizontal heart show evidence of backward rotation of the apex and clockwise rotation.

One horizontal heart shows backward rotation of the apex as its sole change.

The case showing no change is a vertical heart.

A shift of the q wave occurs in three cases. In each instance it is to the right, in one case from V5 to V4. In the other two cases marked clockwise rotation is present in the control and a q wave appears in V6 in the right lateral posture. This can only be explained on the assumption that counter-clockwise rotation has occurred.

Left lateral posture (F).

In all twenty cases there is evidence of displacement of the heart to the left. In addition nineteen cases show forward rotation of the apex and one case shows forward rotation of the apex with counter-clockwise rotation.

A shift of the q wave occurs in five cases and in each case it is to the right. Four of these are vertical hearts; three of them with marked clockwise rotation in the control show a q wave in V6 in the left lateral posture while the fourth case has a shift of the q wave from V6 to V5. The one horizontal heart has marked clockwise rotation in the control and shows a q wave in V6 in the left lateral posture. All these changes can be explained by forward rotation of the apex.

<u>Prone posture (G)</u>.

Changes occur in all twenty cases.

Nine cases show evidence of forward rotation of the apex, five being vertical and four horizontal hearts. Three of the vertical hearts also show evidence of becoming less vertical and three of the horizontal hearts show evidence of becoming more horizontal.

Two vertical hearts and one horizontal heart show evidence of forward rotation of the apex and counter-clockwise rotation.

One vertical and one horizontal heart show evidence of counter-clockwise rotation alone.

Three vertical hearts show evidence of becoming less vertical as their sole change.

Three horizontal hearts show evidence of becoming more horizontal as their sole change.

A shift of the q wave occurs in four cases and in each case it is to the right. Three of these are vertical hearts with marked clockwise rotation in the control and all show a q wave in V6 in the prone posture.

The remaining case is a horizontal heart and it shows a shift of the q wave from V6 to V5. All these changes are probably due to a combination of forward rotation of the apex and counter-clockwise rotation.

P wave.

No noteworthy changes occur in the P wave in any of the postures apart from an increase in the P waves in V4 to V6 in one case in the sitting, standing and 45° head up postures and alteration of upright to diphasic P waves in V1 and V2 in two cases in the left lateral posture.

T wave.

The control tracings (D) show that in fourteen cases the T waves in V1 to V6 are upright. Of the remaining six cases, one has a flat T wave in V1, one has flat T waves in V1 to V3 and diphasic T waves in V4 to V6, one has diphasic T waves in V1 to V5, one has diphasic T waves in V2 to V4, one has an inverted T wave in V1 and diphasic T waves in V2 to V6 and one has diphasic T waves in V5 and V6.

Sitting posture (A)

Changes in the T waves occur in fifteen of the twenty cases.

The main change is that the T waves particularly over the left side of the precordium become less positive. Only two exceptions occur. In one, the T wave becomes more positive in V1 to V3 and less positive in V4 to V6 and in one it becomes more positive in V4 to V6.

Two cases with upright T waves in V1 in the control show inverted T waves in the sitting posture; one case with a diphasic T wave in V1 in the control shows an inverted T wave in the sitting posture and one case with a diphasic T wave in V1 in the control shows a less positive though still diphasic T wave in the sitting posture. In one of the exceptions already mentioned a flat T wave in V1 in the control becomes upright in the sitting posture.

Standing posture (B).

Changes in the T waves occur in nineteen of the twenty cases.

The main change is that the T waves particularly over the left side of the precordium become less positive. Only two exceptions occur. In one the T wave becomes more positive in V3 and V4 and less positive in V6 and in one the T wave becomes more positive in V4 to V6.

One case with an upright T wave in V1 in the control has an inverted T wave in V1 in the standing posture; one case with a diphasic T wave in V1 in the control has an inverted T wave in V1 in the standing posture; one case with an upright T wave in V1 in the control has a diphasic T wave in V1 in the standing posture; one case with an upright T wave in V1 in the control has a flat T wave in V1 in the standing posture; one case with an upright T wave in V6 in the control has a diphasic T wave in V6 in the standing posture; and one case with upright T waves in all leads in the control has diphasic T waves in V1 and V4 to V6 in the standing posture.

45° head up posture (C).

Changes in the T waves occur in nineteen of the twenty cases. The one case showing no change also shows no change in posture (B).

Again as in posture (B) the main change is that the T waves particularly over the left side of the precordium become less positive. The two exceptions are the same as in posture (B).

One case with an upright T wave in V1 in the control has an inverted T wave in V1 in the 45° head up posture; one case with a diphasic T wave in V1 in the control now has an inverted T wave in V1; one case with an upright T wave in V1 in the control now has a diphasic T wave in V1; and one case with an upright T wave in V6 in the control now has a diphasic T wave in V6.

It is evident therefore that the changes in this posture are similar to those in posture (B) but are less obvious.

Right lateral posture (E).

Changes in the T wave occur in eighteen of the twenty cases. The individual leads affected vary considerably from case to case but the general tendency is for the T waves in V1 and V2 or V1 to V3 to become more positive and for the T waves in V4 or V5 to V6 to become less positive. There are five exceptions however. In two cases the T wave becomes more positive in all leads; in one case it becomes less positive in all leads; in one case it becomes more positive in V3 to V6; and in one case it becomes more positive in V6.

Left lateral posture (F).

Changes in the T waves occur in all twenty cases. The individual leads affected vary considerably from case to case but the general tendency is for the T waves in V1 and V2 or V1 to V3 to become less positive and for the T waves in V3 or V4 to V6 to become more positive. There are five exceptions however. In one case the T wave becomes less positive in all leads; in one case it becomes less positive in V1, V2 and V6; in one case it becomes less positive in V6; in one case it becomes less positive in V1 and V6 and more positive in V2 and V3; and in one case it becomes more positive in V1 and less positive in V2 to V6.

Three cases with upright T waves in V1 in the control have inverted T waves in V1 in the left lateral posture; one case with a diphasic T wave in V1 in the control now has an inverted T wave in V1; one case with an upright T wave in V1 in the control now has a diphasic T wave in V1; and one case with a flat T wave in V1 in the control now has an inverted T wave in V1.

Prone posture (G).

Changes in the T waves occur in nineteen of the twenty cases. The individual leads affected vary considerably from case to case but the general tendency is for the T waves in V1 and V2 to become less positive and for the T waves in V3 or V4 to V6 to become more positive. There are five exceptions however. In one case the T wave becomes less positive in all leads; in one case it becomes less positive in V1 and V2 and in V5 and V6; in one case it becomes less positive in V1 and V6; in one case it becomes less positive in V5 and V6; and in one case it becomes less positive in V6.

Three cases with upright T waves in V1 in the control have inverted T waves in the prone posture and one case with a diphasic T wave in V1 in the control now has an inverted T wave in V1.

The changes in general therefore tend to resemble those in the left lateral posture but they are less obvious.

SECTION 11.

The Effect of Posture on the Abnormal Electrocardiogram.

1V. Correlation of Standard Limb, Unipolar Limb and Precordial Leads.

In this section the individual changes which have been described in the three types of lead in the twenty abnormal cases are correlated.

The results are very similar to those obtained in the normal cases and are therefore dealt with more briefly.

Sitting, Standing and 45° head up postures (A, B and C).

In these postures the changes in the QRS complex, P wave and T wave in the three types of lead are similar in nature and frequency to those in the normal series, and the same conclusions are applicable.

Right lateral posture (E).

In this posture the changes are on the whole similar to those in the normal series. There are two points of difference however. (1) The changes in the QRS complexes in the standard and unipolar limb leads tend to be more consistent. Thus in the standard leads seventeen cases show a shift of the QRS axis to the left and only two cases show a shift to the right; the remaining case shows no change. In the unipolar limb leads fourteen cases show evidence of counter-clockwise rotation around the antero-posterior axis and only four cases show clockwise rotation; the remaining two cases show no change. (2) Changes in the T waves in the precordial leads are complicated in some cases by pre-existing abnormality in these waves due to the cardiac lesion. Thus, though in most cases the T wave still tends to be increased in V1 to V3 and decreased in V4 to V6, exceptions to this rule occur in five of the twenty cases. This probably also accounts for the greater diversity of change in the T waves in the standard and unipolar limb leads.

Left lateral posture (F).

In this posture the changes in the QRS complexes in the three types of lead are similar in frequency and nature to those in the normal series. As in posture (E) however, the T wave changes in the precordial leads are exceptional in five of the twenty cases.

Prone posture (G).

In this posture the changes in the QRS complexes in the three types of lead are similar in frequency and nature to those in the normal series but again as in postures (E) and (F) the T wave changes in the precordial leads are exceptional in five of the twenty cases.

In conclusion, it would appear that the postural changes in the normal and abnormal groups are very much alike both in frequency and type. This applies particularly to the effects of rotation and displacement as assessed by changes in the QRS complexes. The uniformity of the T wave changes in postures A, B and C in both groups as opposed to the discrepancies encountered in postures E, F and G may well be due to the fact that in the former set of postures the T wave changes are due in part to a common neurogenic factor whereas in the latter set of postures the changes are purely due to the effect of rotation and displacement.

PART V.

POSTURAL INVERSION OF THE T WAVE IN STANDARD LEADS 11 AND 111.

PART V.

POSTURAL INVERSION OF THE T WAVE IN STANDARD LEADS 11 AND 111.

SECTION 1.

Historical Introduction.

One of the most interesting effects of posture on the electrocardiogram is the phenomenon of flattening or inversion of the T waves in leads 11 and 111 in apparently normal subjects on changing from the recumbent to the sitting or standing position. This seems to have been noted first by Jensen et al (1932). Since then various investigations have been carried out with a view to determining the cause and significance of these changes. The effect was at one time attributed to latent heart disease (Leimdorfer, 1935) but subsequent observers have agreed that the main cause is an alteration in the position of the heart with perhaps a contributory autonomic nervous influence (Sigler, 1938; White and Chamberlain, 1938; Ylvisaker and Kirkland, 1940; Scherf and Weissberg, 1941; White et al, 1941). Full inspiration may enhance the effect while full expiration tends to abolish it (Scherf and Weissberg, 1941; White et al, 1941). Although it occurs most commonly in young slimly built individuals (White et al, 1941) it does not seem to be unduly frequent in so-called neuro-circulatory asthenia (Logue et al, 1944). It has been noted, however, that in normal individuals displaying the characteristic limb lead changes, the chest leads CF2, CF3 and CF4 are unaffected, while in the emotionally unstable subjects the T waves in these leads are also lowered or inverted (Wendkos, 1944).

Similar depression of the T waves in leads 11 and 111 is known to occur in normal individuals after the administration of nitro-glycerine (Scherf and Weissberg, 1941) and after inhalation of amyl nitrite (Goldberger, 1945b). It has been suggested that the inversion of the T wave in lead 111 in these cases is due to inversion of T in lead aVF and that the standing posture, inspiration and amyl nitrite all produce this effect by the same mechanism, namely, clockwise rotation around the longitudinal axis and forward rotation of the apex around the transverse axis in a vertical heart (Goldberger and Schwartz, 1946). More recently, however, Goldberger (1949c) has admitted that in some of these cases a concomitant lowering or inversion of the T waves in the unipolar chest leads may occur in the standing posture which cannot be attributed to any change in position of the heart and is therefore presumably due to sympathetic stimulation consequent on a diminished venous return.

It was considered that further study of this problem with the unipolar leads might yield information of value and the results of these investigations are described in the following sections of this thesis.

SECTION 2.

General Description of the Cases Studied.

Two cases showing postural inversion of the T waves in leads 11 and 111 were selected for detailed study.

CASE 1. A.R. Age 18 years.

This was a healthy male subject. There was no previous history of illness and clinical examination revealed no abnormality. There was no evidence of emotional instability. Radiological examination of the chest and heart was negative.

The electrocardiogram in the recumbent posture showed the following appearances:

Standard Limb Leads.

Lead 1 has upright P and T waves and a qRs pattern.

Lead 11 has upright P and T waves and a tall R pattern.

Lead 111 has upright P and T waves and a small splintered R pattern.

Unipolar Limb Leads.

aVR has inverted P and T waves and a QS pattern.

aVL has low upright P and T waves and a qRS pattern.

aVF has upright P and T waves and a slightly splintered R pattern.

Precordial Leads.

V1 and V2 have rS patterns.

V3 to V5 have Rs patterns.

V6 has an R pattern.

The P and T waves are upright in all leads.

The heart is horizontal with marked clockwise rotation.

CASE 2. A.McL. Age 17 years.

This was a healthy male subject. There was no previous history of illness and clinical examination revealed no abnormality. There was no evidence of emotional instability. Radiological examination of the chest and heart was negative.

The electrocardiogram in the recumbent posture showed the following appearances:

Standard Limb Leads.

Lead 1 has upright P and T waves and a qRs pattern.

Lead 11 has upright P and T waves and a tall R pattern.

Lead 111 has upright P and T waves and a slightly splintered R pattern.

Unipolar Limb Leads.

aVR has inverted P and T waves and a QS pattern.

aVL has diphasic or slightly inverted P waves and low upright T waves and a qrS pattern.

aVF has upright P and T waves and a slightly splintered R pattern.

Precordial Leads.

V1 to V3 have rS patterns.

V4 has an RS pattern.

V5 and V6 have qRs patterns.

The heart is horizontal with moderate clockwise rotation.

It can be seen that the electrocardiographic patterns in the two cases are similar. On standing, inversion of the T wave in leads 11 and 111 occurred in both cases, but was less marked in Case 1 than in Case 2.

SECTION 3.

The Effect of Repeated Lying and Standing.

The objects of this experiment were to determine, firstly, whether the alterations in the electrocardiogram occurred immediately after the change from the lying to the standing posture or vice versa, and secondly, whether they were reproduced consistently with repeated changes in posture.

Method.

Eight recordings of each lead were made with the subject alternately lying and standing, the whole procedure being carried out as quickly as possible.

In Case 1 the three standard leads were investigated in this way. In Case 2 the three unipolar limb leads were investigated in addition to the standard leads.

Results.

The complete sets of tracings from the two cases are shown in plates 187 to 189.

CASE 1.

The electrocardiographic patterns in the lying posture are all identical.

The patterns in the standing posture are all identical. The alterations which occur on standing are as follows:

The heart rate is increased from 80 per minute to 100 per minute.

The P wave is increased in leads 11 and 111.

There is a shift of the QRS axis to the right.

The T wave is reduced in all leads and becomes inverted in lead 111.

CASE 2.

The electrocardiographic patterns of the standard leads in the lying posture are all identical.

The patterns in the standing posture are all identical. The alterations which occur on standing are as follows:

The heart rate is increased from 70 per minute to 100 per minute.

The P wave is increased in leads 11 and 111.

There is a shift of the QRS axis to the right.

The T wave is reduced in all leads and becomes inverted in leads 11 and 111.

The electrocardiographic patterns of the unipolar limb leads in the lying posture are all identical.

The patterns in the standing posture are all identical. The alterations which occur on standing are as follows:

The heart rate is increased from 70 per minute to 100 per minute.

The P wave is more negative in aVL and more positive in aVF.

The S wave is increased in aVL; the R wave is increased in aVF.

The T wave is less inverted in aVR; it is increased in aVL and becomes inverted in aVF.

Conclusions.

Alterations in the standard and unipolar limb leads occur immediately after changing from the lying to the standing posture and are immediately reversible on resuming the lying posture.

These alterations appear consistently on rapid repeated change from the one posture to the other.

SECTION 4.

The Effect of Prolonged Standing.

The object of this experiment was to determine whether the alterations in the electrocardiogram due to the change from the lying to the standing posture persisted when the standing posture was maintained for some time.

Method.

The standard and unipolar limb leads were studied in two cases. A control set of tracings was taken with the subject in the lying posture. The subject then stood at ease and another set of tracings was taken. This posture was maintained for a period of one hour and further sets of tracings were taken at five minute intervals during the first half hour and at ten minute intervals during the second half hour. At the end of this period the subject resumed the lying posture and a final set of tracings was taken.

Results.

The complete sets of tracings from the two cases are shown in plates 190 to 193.

CASE 1.

On adoption of the standing posture the following alterations in the electrocardiogram immediately occur.

Standard Limb Leads.

The heart rate is increased from 84 per minute to 115 per minute.

The P wave is increased in leads 11 and 111.

There is a shift of the QRS axis to the right.

The T wave is reduced in all leads and becomes flat in lead 11 and inverted in lead 111.

Unipolar Limb Leads.

The heart rate is increased from 84 per minute to 115 per minute.

The P wave becomes inverted in aVL and is increased in aVF.

The pattern in aVL changes from qRS to rS with increase in S; R is increased in aVF.

The T wave becomes much less negative and indeed is practically flat in aVR; it is increased in aVL and becomes inverted in aVF.

During the next hour these alterations in the heart rate, QRS patterns and P wave patterns persist. The alterations in the T wave patterns persist for 15 to 20 minutes. Thereafter the patterns tend to revert to the appearances in the lying posture. Thus after one hour T is upright again in lead 111 and in aVF. The T wave in the standard leads does not become as tall as in the lying posture. In aVL the T wave becomes identical with that in the lying posture but this does not occur in aVR or aVF.

On resuming the lying posture at the end of one hour the patterns in all the leads immediately become identical with those of the original control series.

CASE 2.

On adoption of the standing posture the following alterations in the electrocardiogram immediately occur.

Standard Limb Leads.

The heart rate is increased from 74 per minute to 115 per minute.

The P wave is increased in leads 11 and 111.

There is a shift of the QRS axis to the right.

The T wave is reduced in all leads and becomes inverted in leads 11 and 111.

Unipolar Limb Leads.

The heart rate is increased from 74 per minute to 115 per minute.

The P wave becomes inverted in aVL and is increased in aVF.

The pattern in aVL changes from qRS to rS with increase in S; R is increased in aVF.

The T wave becomes upright in aVR; it is increased in aVL and becomes deeply inverted in aVF.

During the next hour these alterations in the heart rate, P wave patterns and QRS patterns persist. The alterations in the T wave patterns persist for 30 to 35 minutes. Thereafter the patterns tend to show some reversion towards their appearances in the lying posture. At the end of one hour, however, the T wave is still inverted in leads 11 and 111 and in aVF.

On resuming the lying posture after one hour the patterns in all the leads immediately become identical with those of the original control series, apart from slight increase of the T wave in leads 11 and 111 and in aVF, and increased inversion of the T wave in aVR.

Conclusions.

The alterations in the electrocardiogram due to the change from the lying to the standing posture are at their maximum immediately after assuming the standing posture, and show no tendency to develop further when the standing posture is maintained.

The alterations in the heart rate, P waves and QRS complexes persist for at least an hour.

The alterations in the T waves appear to be more transient. They persist for 20 to 30 minutes and thereafter show some tendency to regress. Even after one hour, however, the alterations are still obvious.

A comparison of the two cases described shows that the effect on the T waves of the change in posture is quantitative as well as qualitative.

On resuming the lying posture after prolonged standing the patterns revert at once to their original form.

SECTION 5.

The Effect of Exercise on the Electrocardiographic Patterns produced by Standing.

The object of this experiment was to determine whether the electrocardiographic patterns in the standing posture are affected by exercise.

Method.

The standard and unipolar limb leads were studied in two cases. A control set of tracings was taken with the subject in the lying posture. A further set of tracings was taken with the subject standing. He then hopped fifty times on each foot and a further set of tracings was then taken in the standing posture. Two sets of tracings were taken at five minute intervals thereafter. The subject then lay down and a final set of tracings was taken.

Results.

The complete sets of tracings from the two cases are shown in plates 194 and 195.

CASE 1.

The standard and unipolar limb leads before and after exercise in the standing posture are identical.

The differences between the patterns in the lying and standing postures are as already described in Sections 3 and 4.

CASE 2.

The standard and unipolar limb leads before and after exercise in the standing posture are very similar. The only difference is in the T waves which are slightly more positive in lead 1 and less inverted in leads 11 and 111 after exercise. This is associated with a slightly more negative T wave in aVR and less negative T wave in aVF.

The differences between the patterns in the lying and standing postures are as already described in Sections 3 and 4.

Conclusion.

Exercise has practically no effect on the electrocardiographic changes due to standing.

SECTION 6.

A Comparison of the Effect of Respiration on the Electrocardiogram in the Lying and Standing Postures.

The objects of this experiment were to determine firstly whether there was any difference between the effects of respiration on the electrocardiogram in the lying and standing postures, and secondly, whether deep respiration in the standing posture counteracted or exaggerated the postural effect.

Method.

The standard and unipolar limb leads were studied in two cases.

With the subject in the lying posture a control tracing was taken during quiet breathing. Tracings were then taken with the breath held in deep inspiration and in forced expiration. This procedure was then repeated in the standing posture.

Results.

The complete sets of tracings from the two cases are shown in plates 196 and 197.

CASE 1.

Lying Posture.

The standard leads show a shift of the QRS axis to the right on inspiration and a shift to the left on expiration.

The unipolar limb leads show the following changes. On inspiration, the pattern in aVL changes from qRS to qrS; in aVF R is increased; the T wave is less inverted in aVR and is reduced in aVL and aVF. On expiration, aVL has a qRs pattern with increase in R; in aVF R is reduced.

Standing Posture.

The control series of standard limb leads show the following postural effects:

The heart rate is increased from 82 per minute to 115 per minute.

The P wave is increased in leads 11 and 111.

There is a shift of the QRS axis to the right.

The T wave is reduced in all leads and becomes inverted in lead 111.

On inspiration the heart rate is unchanged but most of the other postural effects are exaggerated. Thus the P wave is further increased in leads 11 and 111; there is a further shift of the QRS axis to the right; the T wave becomes inverted in lead 11 and more deeply inverted in lead 111. The one exception is the T wave in lead 1 which is increased slightly.

On expiration, the heart rate remains unaltered but the other postural effects are partially counteracted. Thus the P wave is reduced in leads 11 and 111; there is a shift of the QRS axis to the left; the T wave is increased in leads 1 and 11 and becomes diphasic in lead 111.

The control series of unipolar limb leads show the following postural effects:

The heart rate is increased from 82 per minute to 115 per minute.

The P wave is inverted in aVL and increased in aVF.

The pattern in aVL changes from qRS to rS with increase in S; in aVF R is increased.

The T wave is less inverted in aVR and is reduced in aVF.

On inspiration, the heart rate is unchanged but the other postural effects are exaggerated. Thus the T wave is flattened in aVR, increased in aVL and becomes inverted in aVF.

On expiration, the heart rate remains unaltered but the other postural effects are partially counteracted. Thus the P wave becomes upright in aVL and is reduced in aVF. The pattern in aVL changes to qRs; in aVF R is reduced. The T wave becomes inverted in aVR and upright in aVF.

CASE 2.

Lying Posture.

The standard leads show a shift of the QRS axis to the right on inspiration with some reduction of the T waves in leads 1 and 11. On expiration no significant changes occur.

The unipolar limb leads show no significant changes with either inspiration or expiration.

Standing Posture.

The control series of standard limb leads show the following postural effects:

The heart rate is increased from 74 per minute to 100 per minute.

The P wave is increased in leads 11 and 111.

There is a shift of the QRS axis to the right.

The T wave is reduced in all leads and becomes flat in lead 11 and inverted in lead 111.

On inspiration, the heart rate is practically unchanged but most of the other postural effects are exaggerated. Thus the P wave is further increased in leads 11 and 111; there is a further shift of the QRS axis to the right; the T wave becomes slightly inverted in lead 11. The one exception is the T wave in lead 1 which remains unaltered.

On expiration, the heart rate is unchanged but the other postural effects are partially counteracted. Thus the P wave is reduced in leads 11 and 111; there is a shift of the QRS axis to the left; the T wave is increased in lead 1 and becomes flat in lead 11.

The control series of unipolar limb leads show the following postural effects:

The heart rate is increased from 74 per minute to 100 per minute.

The P wave is inverted in aVL and increased in aVF.

S is increased in aVL and R is increased in aVF.

The T wave is less inverted in aVR, increased in aVL and inverted in aVF.

On inspiration, the heart rate is unchanged but the other postural effects are exaggerated. Thus the P wave is further inverted in aVL and increased in aVF; the pattern in aVL changes to rS and R is increased in aVF; the T wave becomes flat in aVR, and is more inverted in aVF.

On expiration, the heart rate remains unaltered but the other postural effects are partially counteracted. Thus the P wave is less inverted in aVL and reduced in aVF. The pattern in aVL reverts to qrS and R is reduced in aVF. The T wave becomes inverted in aVR, increased in aVL and less inverted in aVF.

<u>Conclusions.</u>

Deep inspiration tends to exaggerate the alterations in the electrocardiogram due to change from the lying to the standing posture. The increase in the heart rate however is unaffected.

Deep expiration tends to counteract the postural effects, but again the increase in the heart rate is unaffected.

From these two observations it is clear that the postural changes in the electrocardiogram are not entirely due to the associated tachycardia.

SECTION 7.

A Comparison of the Effect of Respiration on the Electrocardiogram in the Right and Left Lateral Postures.

The object of this experiment was to determine whether respiration had any effect on the electrocardiogram in the right and left lateral postures.

Method.

Two cases were studied. In case 1 the standard leads were recorded during quiet breathing, in full inspiration and in forced expiration with the subject lying first in the right lateral posture and then in the left lateral posture. For comparative purposes the effect of respiration in the standing posture was similarly studied.

In case 2 the standard and unipolar limb leads were recorded during quiet breathing, in full inspiration and in forced expiration with the subject lying first in the right lateral posture and then in the left lateral posture.

Results.

The complete sets of tracings from the two cases are shown in plates 198 and 199.

CASE 1.

Standing Posture.

The effects of respiration are similar to those already described in Section 6.

Right Lateral Posture.

Compared with the standing posture the control tracings show reduction of R in all leads; the T wave is upright and of increased amplitude in all leads.

On inspiration the QRS axis shifts slightly to the right. There are no significant changes in the T waves.

On expiration the QRS axis shifts slightly to the left. There are no significant changes in the T waves.

Left Lateral Posture.

The control patterns are similar to those in the right lateral posture but the P wave is reduced in lead 11 and inverted in lead 111; the T wave is reduced in leads 11 and 111.

On inspiration the QRS axis shifts slightly to the right; the P wave in lead 111 becomes diphasic and the T wave in lead 111 is slightly diphasic.

On expiration no significant change occurs.

CASE 2.

Right Lateral Posture.

On inspiration the standard leads show a shift of the QRS axis to the right with reduction of the T wave in leads 1 and 11. The unipolar limb leads show a change of pattern in aVL from qRS to qrS and increase of R in aVF; the T wave is less inverted in aVR and reduced in aVF.

On expiration the standard leads show no significant change. The unipolar limb leads show slight decrease of S in aVL and of R in aVF.

Left Lateral Posture.

The control standard and unipolar limb lead tracings are similar to those in the right lateral posture.

On inspiration the changes are similar to those in the right lateral posture.

On expiration the standard leads show slight reduction of the T waves in leads 11 and 111. The unipolar limb leads show slight increase of the T wave in aVL and slight reduction of the T wave in aVF.

Conclusion.

Respiration has no significant effect on the standard and unipolar limb lead electrocardiogram in either the right or left lateral postures.

SECTION 8.

Effect of Alteration of Position in the 45° head up Posture.

The object of this experiment was to determine whether alteration of bodily position in the 45° head up posture produced any change in the electrocardiogram.

Method.

The standard and unipolar limb leads were studied in one case (case 1). The subject remained in the 45° head up posture throughout. A control set of tracings was taken lying on the back (A). Further sets of tracings were then taken lying on the right side (B), lying on the left side (C) and lying face down (D).

Results.

The complete set of tracings is shown in plate 200.

A. Lead 1 has a qRs, lead 11 an R and lead 111 a splintered R pattern; P and T waves are upright in all leads.

aVR has inverted P and T waves and a QS pattern.

aVL has diphasic P and upright T waves and a qRS pattern. aVF has upright P and T waves and a splintered R pattern.

B. The standard limb leads are similar to those in A but the T wave is slightly increased in lead 1 and reduced in lead 111.

The unipolar limb leads show no significant change.

C. The standard limb leads are similar to those in A but the T wave is increased in lead 1 and reduced in lead 111.

The unipolar limb leads have patterns similar to those in A but the T wave is less inverted in aVR and is reduced in aVF.

D. The standard limb leads are similar to those in A but the T waves are slightly increased in leads 1 and 11 and reduced in lead 111.

The unipolar limb leads are similar to those in A.

Conclusion.

Minor differences are present in the electrocardiogram in the various positions but there is no really significant change.

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STUDIES IN ELECTROCARDIOGRAPHY

APPENDIX A

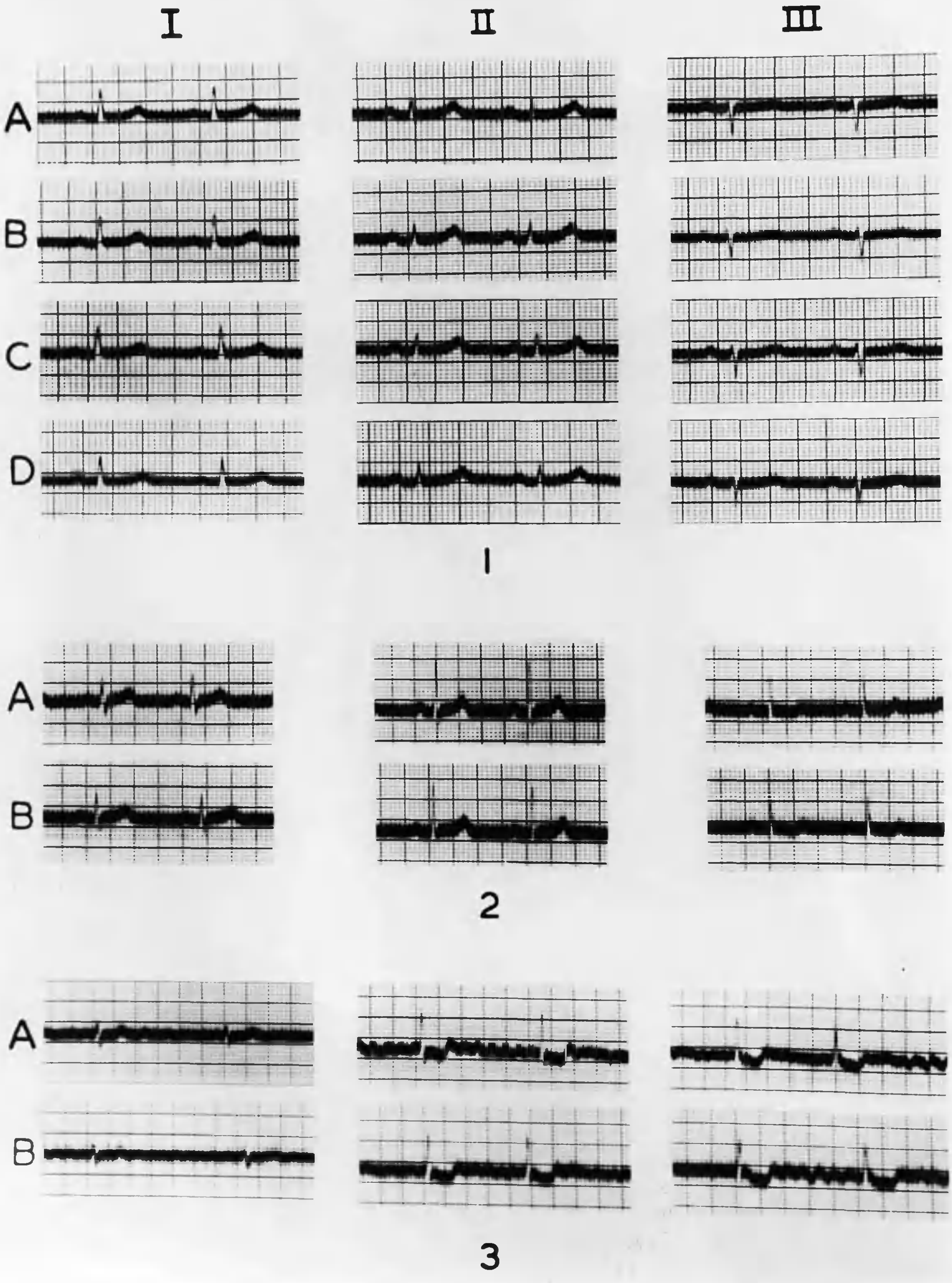
Plates I to 90

PART I.

Section 3.

Plates I to 5.

STANDARD LIMB LEADS



CASE NO.I PLATE I.

J.M.

Age 62 years.

The four sets of tracings A,B,C and D were taken at half-hourly intervals, the electrodes being left in position throughout. The electrocardiograph was switched off between each recording.
The four sets of tracings are identical.

CASE NO.2

A.C.

Age 25 years.

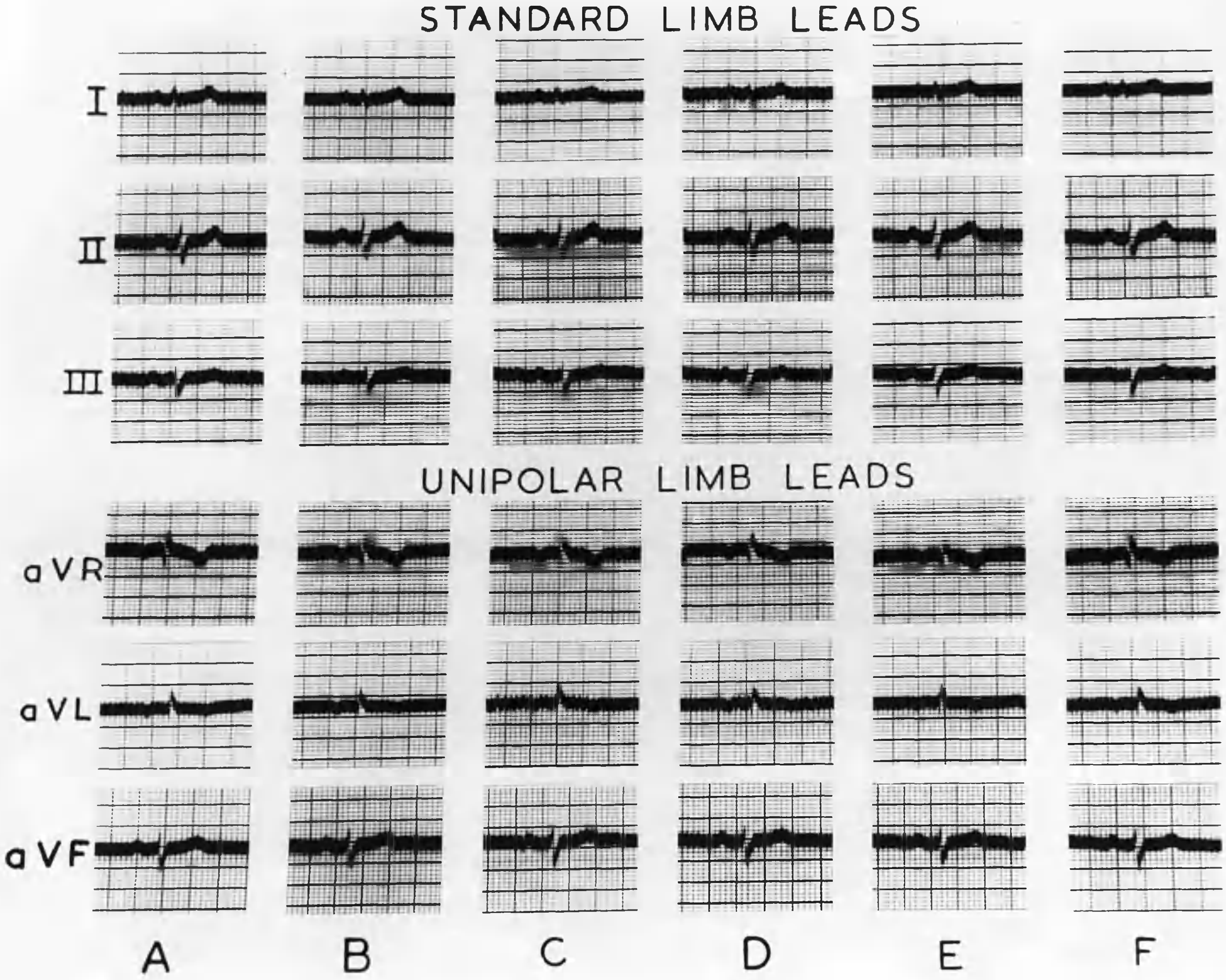
The two sets of tracings A and B were taken in this normal subject at the beginning and end of a two-hour period during which the electrodes were left in position and the electrocardiograph was in continuous action.
The two sets of tracings are identical.

CASE NO.3

J.H.

Age 38 years.

The two sets of tracings A and B were taken in this case of auricular fibrillation with digitalis effect at the beginning and end of a two and a half-hour period during which the electrodes were left in position and the electrocardiograph was in continuous action.
The two sets of tracings are identical.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C
D
E
F

CASE NO.4

PLATE 2a.

W.A.

Age 33 years.

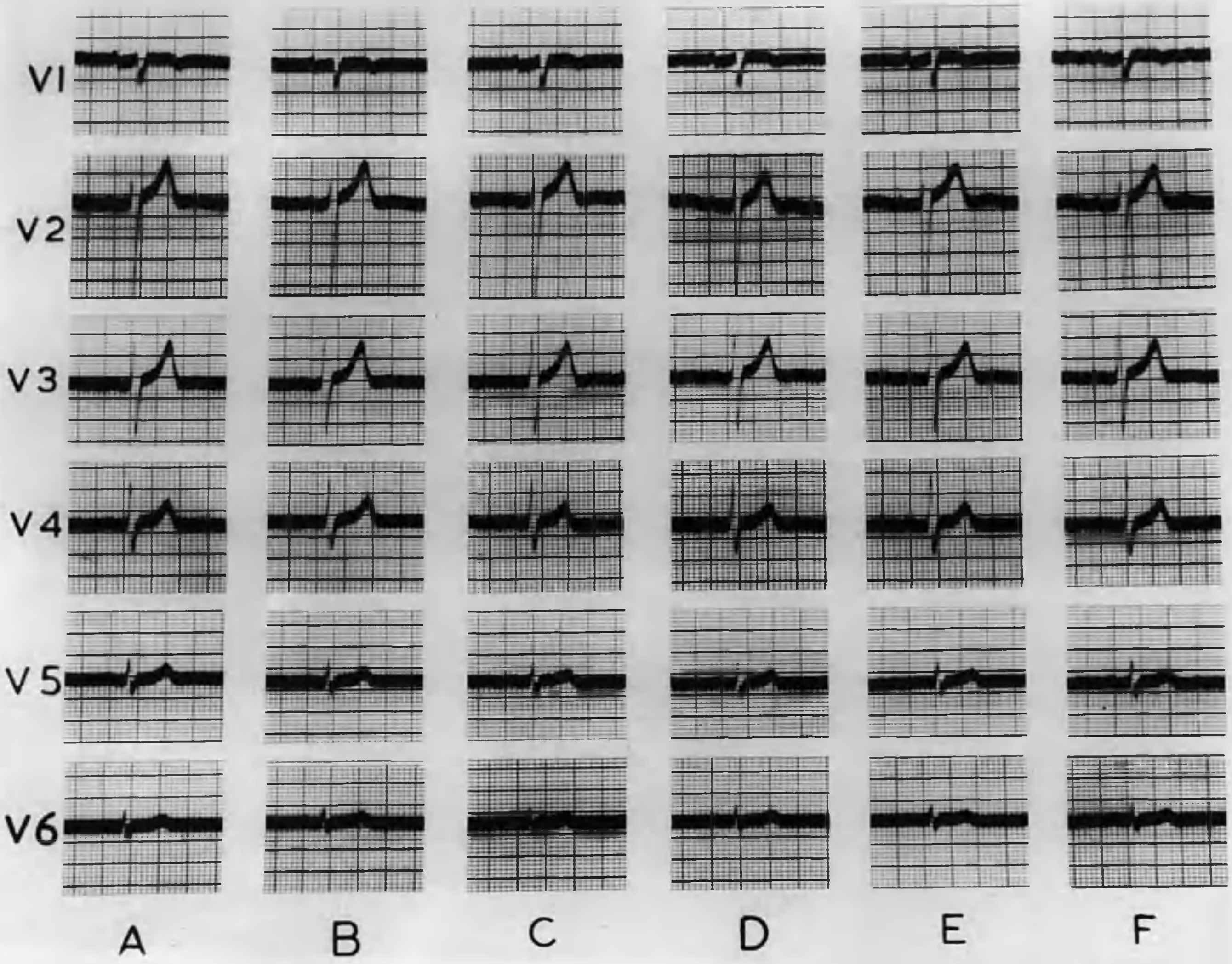
The six sets of tracings A,B,C,D,E and F were taken in this normal subject at half-hourly intervals. The limb electrodes were left in position throughout. The precordial leads were recorded by means of the chest electrodes and the electrode belt described in Section 2 and these also remained in position throughout.

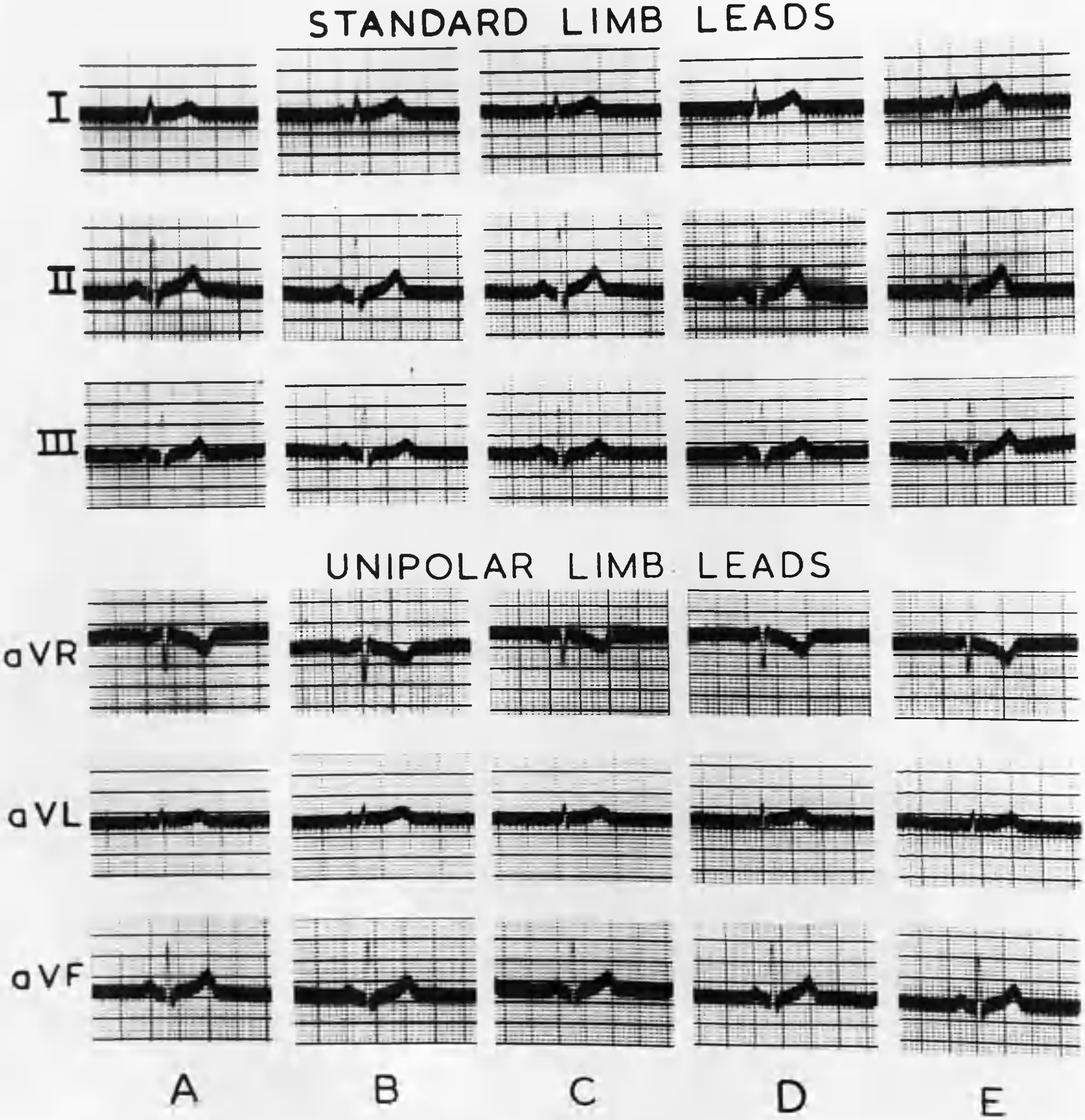
The six sets of tracings are identical.

PLATE 2b.

CASE NO.4.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C
D
E

CASE NO.5

Effect of Food. G.M.

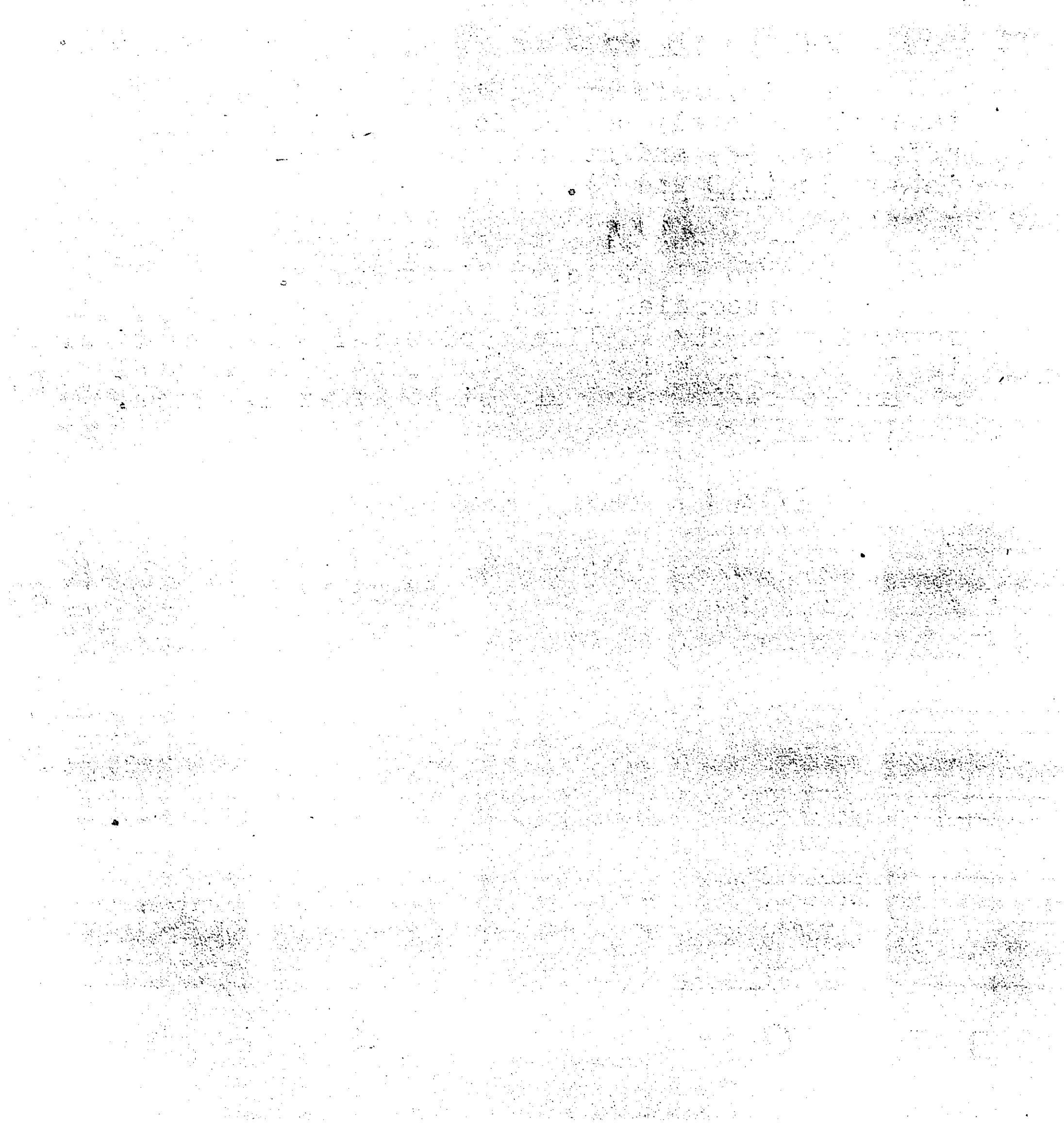
Age 36 years.

The five sets of tracings in this case were taken immediately before food (A), immediately after food (B) and at subsequent half-hourly intervals (C,D and E).

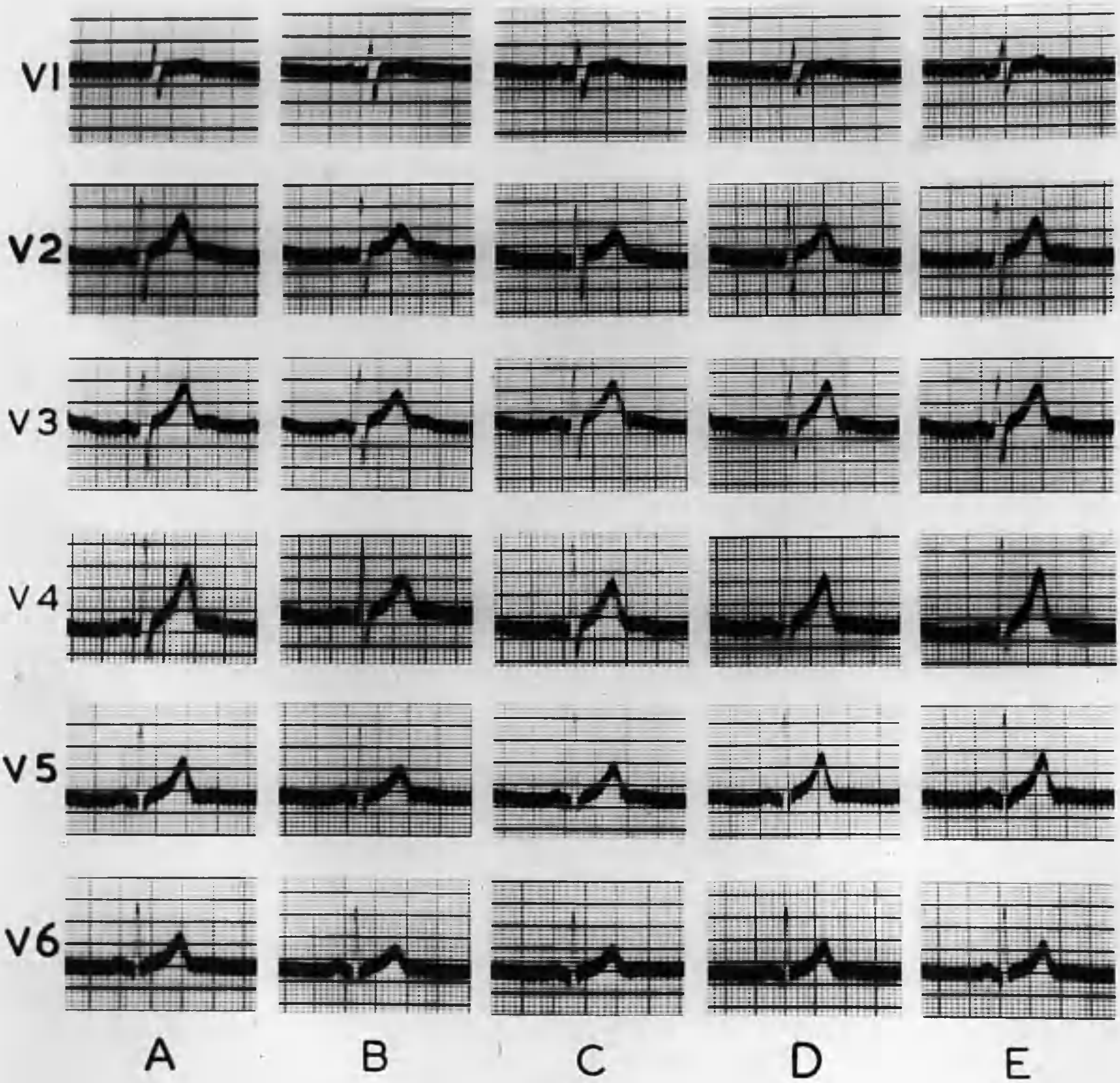
The standard limb leads and unipolar limb leads show no significant differences.

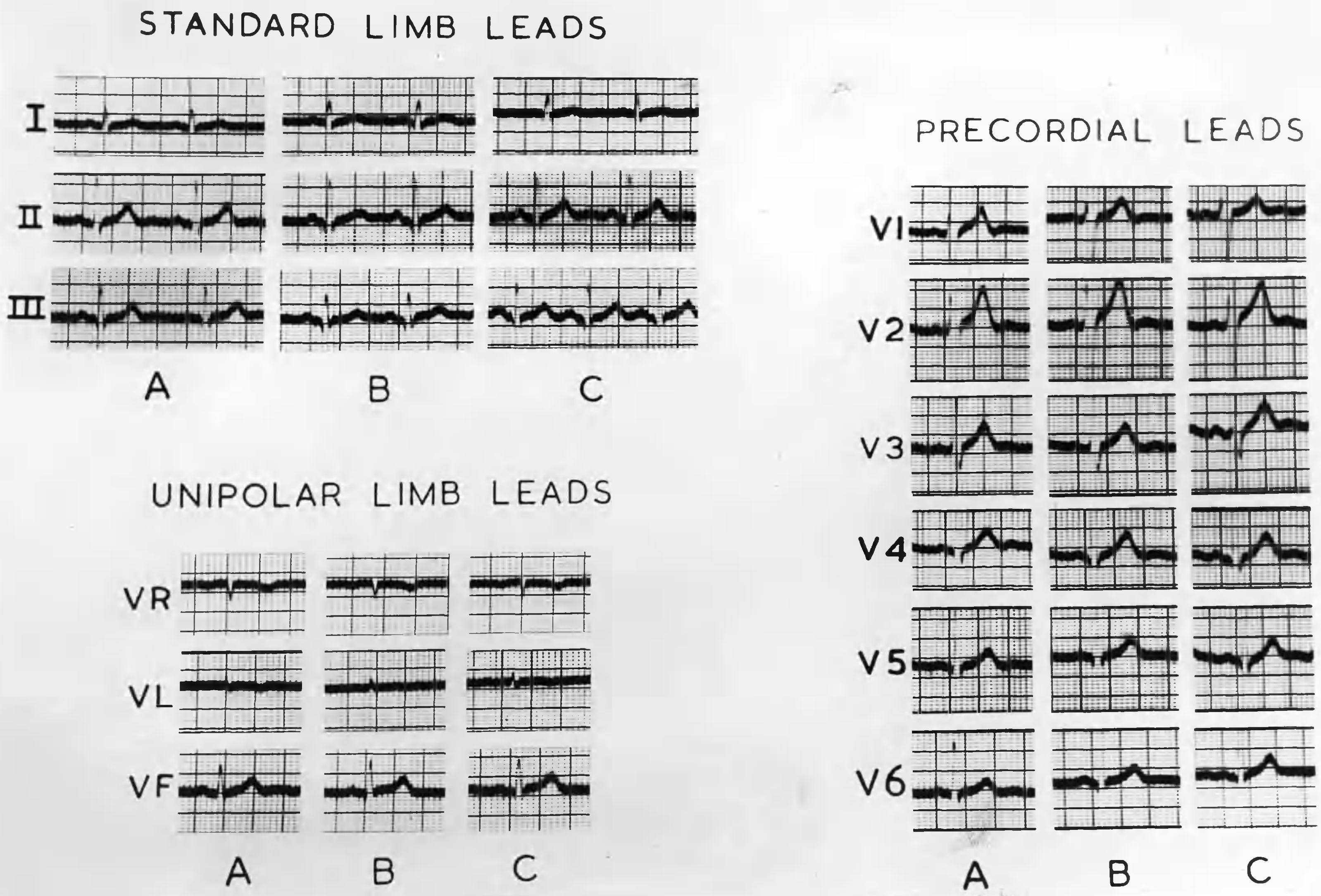
The precordial leads show a very considerable reduction in the amplitude of the T waves particularly in V2 to V5 immediately after food with gradual return to their original height after I½ hours.

PLATE 3b. CASE NO.5.



PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
A
B
C
UNIPOLAR LIMB LEADS
VR
VL
VF
A
B
C
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C

CASE NO.6 PLATE 4.

Effect of Iced and Tepid Water.

A.C.

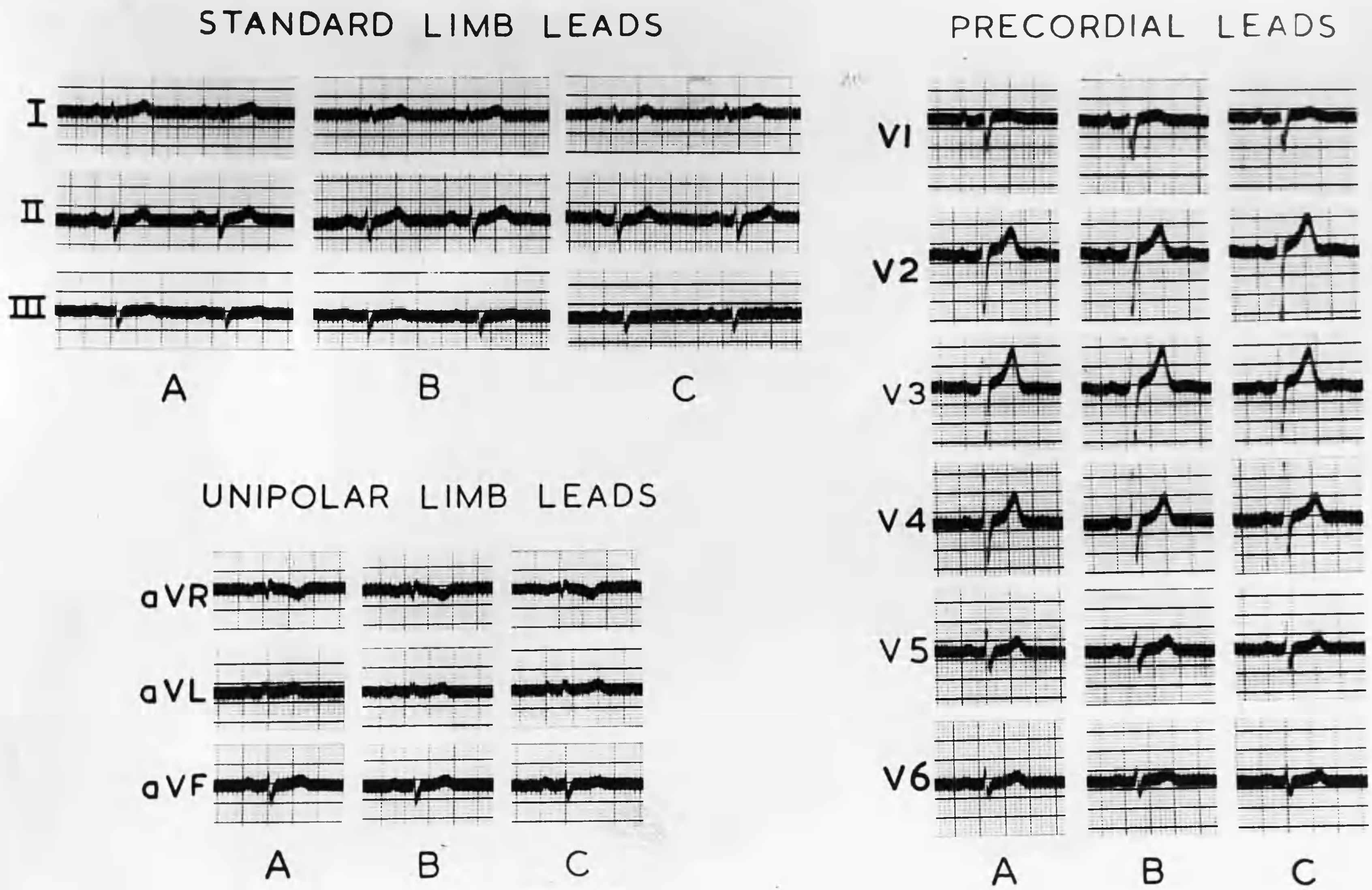
Age 30 years.

The tracings in this case were taken immediately before (A) and immediately after (B) drinking 500 c.c. of iced water. A third series (C) was taken half an hour later after drinking 500 c.c. of tepid water.

The T waves in leads II and III are lowered after drinking the iced water and at the same time the T wave in VL is changed from negative to flat.

The only change in the precordial leads is an increase in the amplitude of the T wave in V2 after drinking the iced water.

The tracings after drinking the tepid water are identical with the control series.


STANDARD LIMB LEADS
I
II
III
A
B
C
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C

CASE NO. 7

PLATE 5.

Effect of Cold Water.

W.A.

Age 33 years.

The tracings in this case were taken immediately before (A) and after (B and C) drinking 500 c.c. of ordinary cold tap water.

The tracings in series B show no differences from the control series.

In series C there is slight flattening of the T wave in lead III and an increase in amplitude of the T wave in V2.

CASE NO. I PLATE 6.

NORMAL. Miss H.F.

Age I5 years.

STANDARD LIMB LEADS.

A: tracings from distal set of electrodes.

B: tracings from proximal set of electrodes.

The two sets of tracings are identical.

UNIPOLAR LIMB LEADS.

A: leads from distal electrodes only.

The W leads are smaller in amplitude than they should be theoretically.

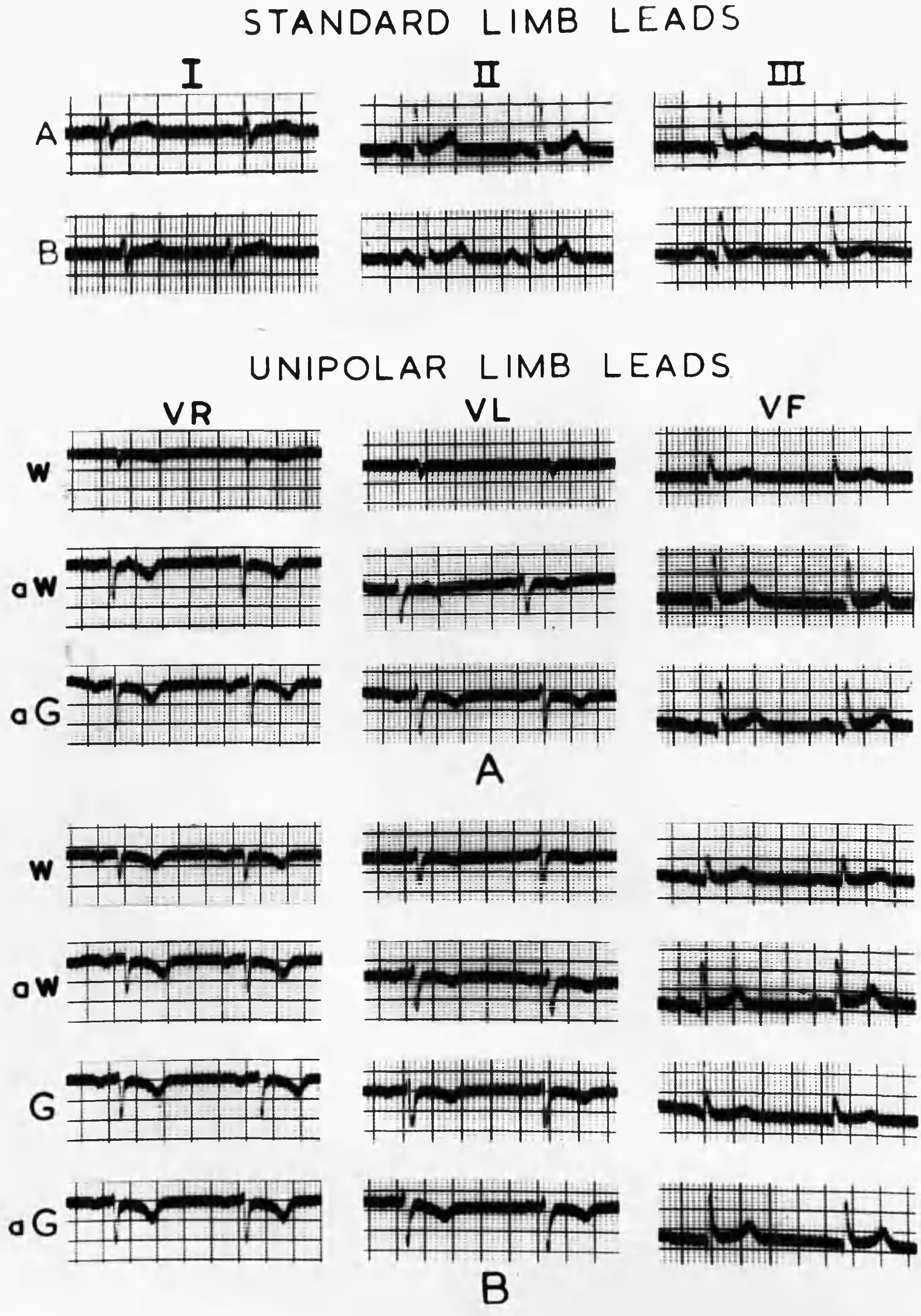
The aW and aG leads are identical with the exception of the P wave in VL, which is low upright in aW and flat in aG.

B: leads from proximal exploring electrodes and distal central terminal.

There is a fairly close correlation between the theoretical and observed values in the four types of lead. The main difference again is in the P wave in VL, which is low upright in W and aW but flat in G and aG.

The aW leads in A and B are identical.

The aG leads in A and B are also practically identical.


STANDARD LIMB LEADS
I
II
III
A
B
UNIPOLAR LIMB LEADS
VR
VL
VF
W
aW
aG
A
W
aW
G
aG
B

CASE NO. 2 PLATE 7.

NORMAL. J.W.

Age 33 years.

STANDARD LIMB LEADS.

A: tracings from distal set of electrodes.

B: tracings from proximal set of electrodes.

The two sets of tracings are practically identical, apart from slight differences in amplitude in the P and T waves in lead III.

UNIPOLAR LIMB LEADS.

A: leads from distal electrodes only.

The W leads particularly VR and VL are much smaller in amplitude than they should be theoretically.

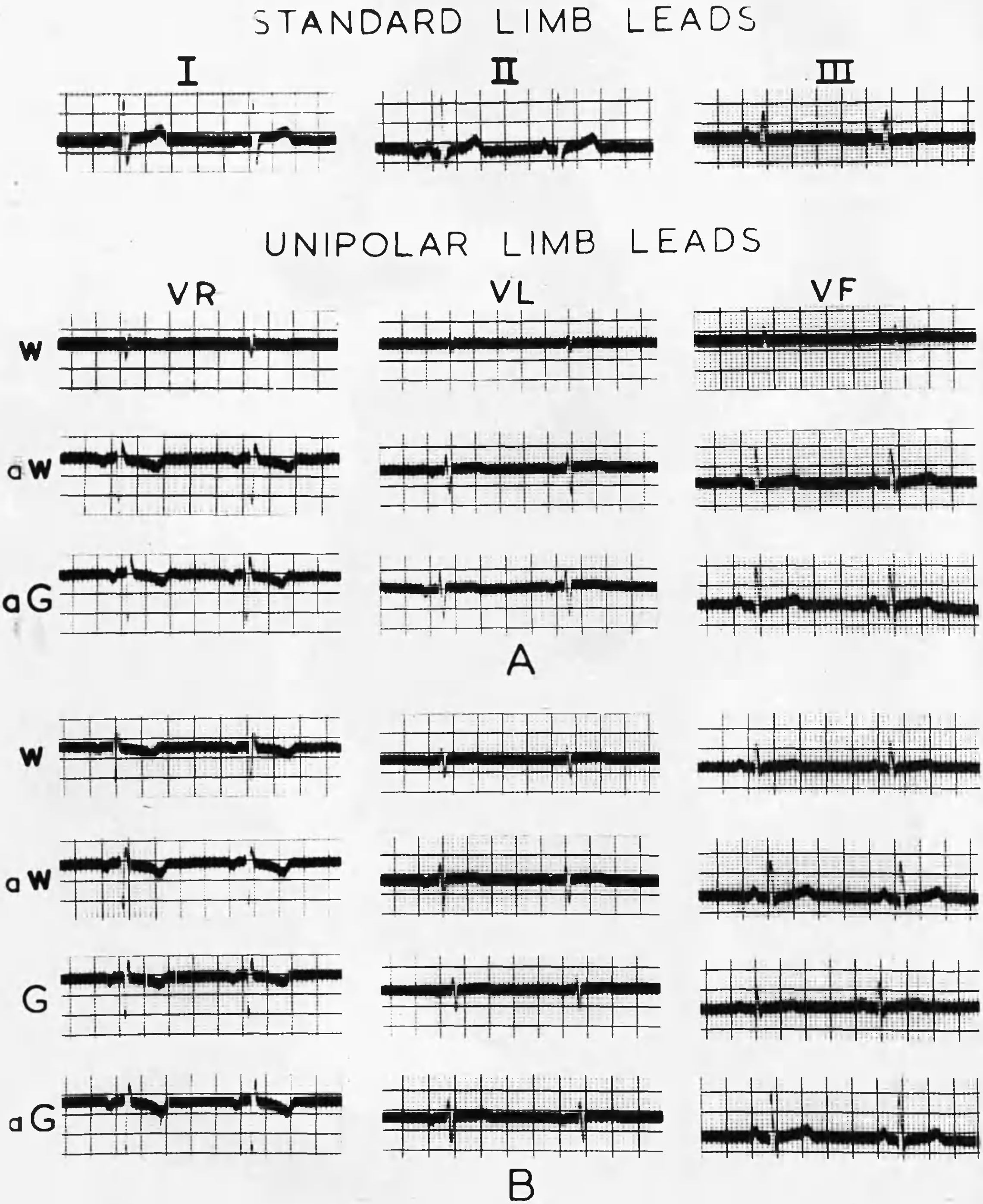
The aW and aG leads show definite differences particularly in VR and VL. All the deflections in the aG leads are greater than those in the corresponding aW leads.

B: leads from proximal exploring electrodes and distal central terminal.

A close correlation exists between the theoretical and observed values of the W and aW leads. This is not so in the case of the G and aG leads. This applies particularly to VR and VL.

The aW leads in A and B are almost identical though there are minor differences in the P waves.

The aG leads in A and B have a fairly close resemblance also but the differences in the P waves are more obvious.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
W
aW
aG
A
W
aW
G
aG
B

CASE NO.3 PLATE 8.

NORMAL. T.R.

Age I9 years.

STANDARD LIMB LEADS.

These were recorded from the distal electrodes only.

UNIPOLAR LIMB LEADS.

A: tracings from distal electrodes only.

The W leads are much smaller in amplitude than they should be theoretically.

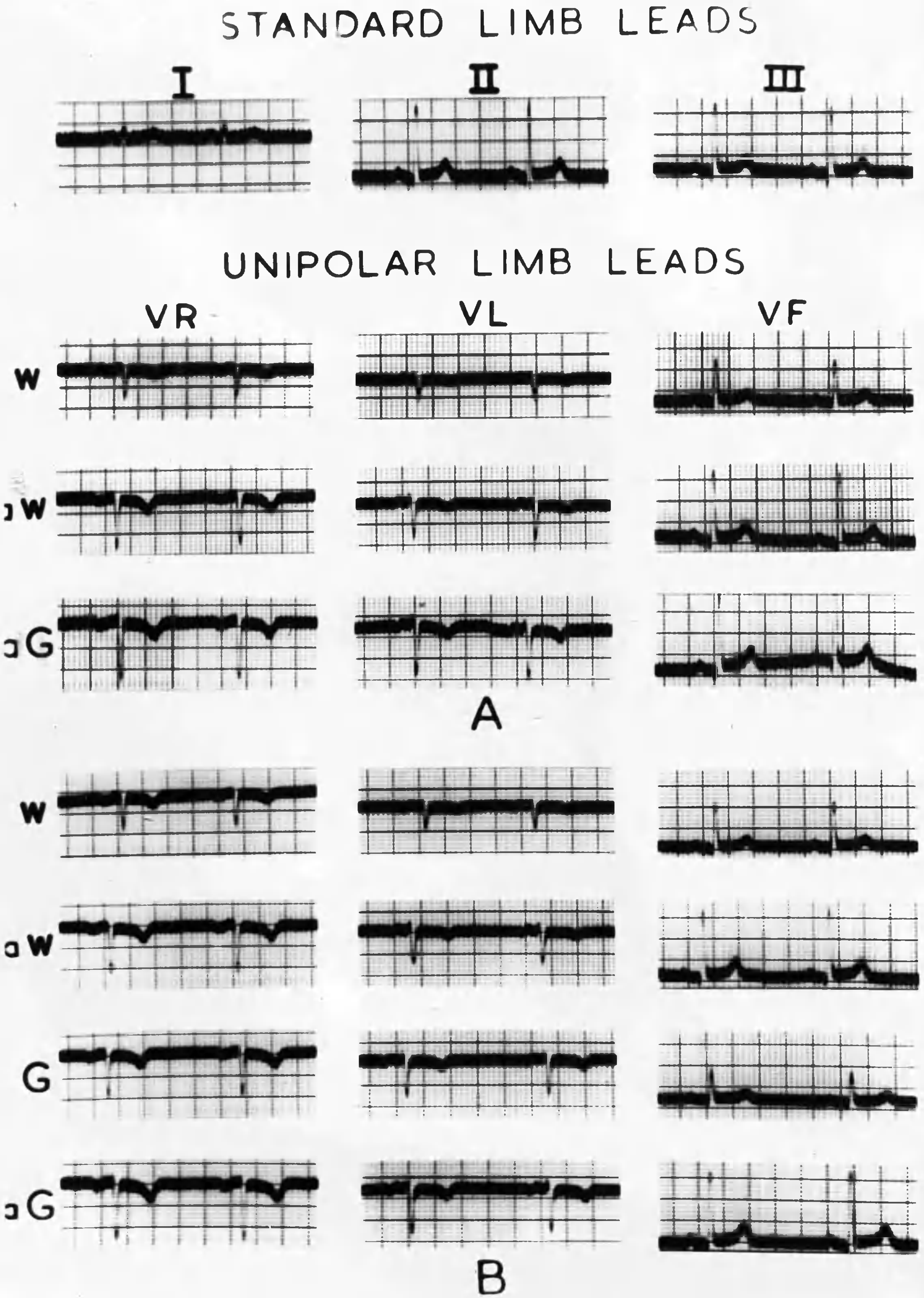
The aW and aG leads show minor differences particularly in the P wave of VL which is less inverted in aW than in aG.

B: leads from proximal exploring electrodes and distal central terminal.

There is a close correspondence between the theoretical and observed values of the W and aW leads. The G and aG leads do not have such a close correspondence. The aW and aG leads show minor differences particularly in the amplitude of the QRS complexes in VR and VF.

The aW leads in A and B are identical.

The aG leads in A and B show minor differences in the amplitude of the QRS complexes and also of the P wave in VL.



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
W
aW
aG
A
W
aW
G
aG
B

CASE NO. 4 PLATE 9.

NORMAL. J.S.

Age 46 years

STANDARD LIMB LEADS.

These were recorded from the distal electrodes only.

UNIPOLAR LIMB LEADS.

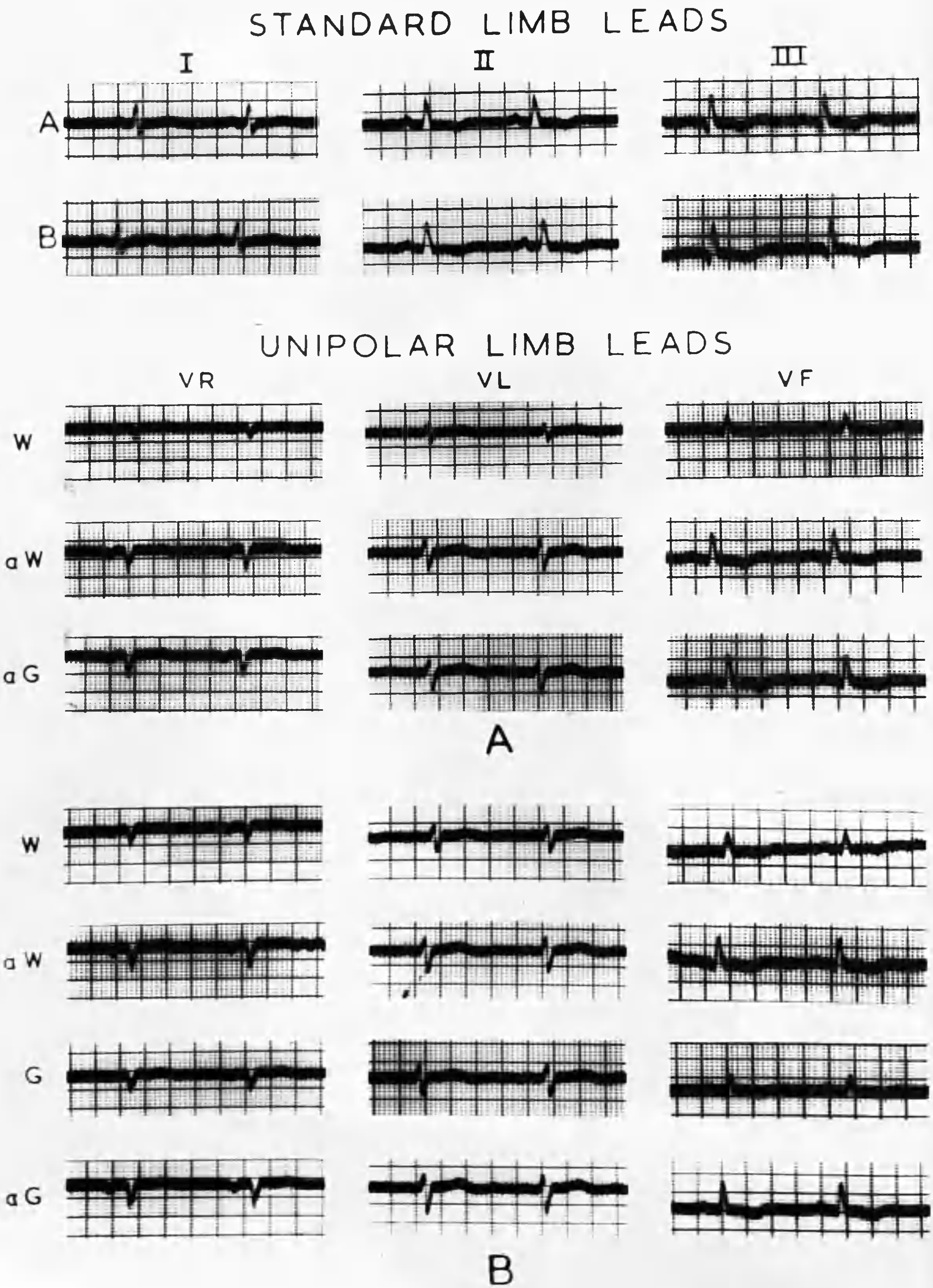
A: tracings from distal electrodes only.

The W leads are slightly smaller in amplitude than they should be theoretically.
The aW and aG leads show differences in the amplitude of the P wave, QRS complex and T wave in VR and VL.

B: leads from proximal exploring electrodes and distal central terminal.

There is a close correspondence between the theoretical and observed values of the W and aW leads. The G and aG leads do not have such a close correspondence as can be seen readily in VF where the deflections are almost three times as great in aG as they are in G.

The aW leads in A and B are identical.
The aG leads in A and B resemble each other fairly closely but there are minor differences in amplitude.


STANDARD LIMB LEADS
I
II
III
A
B
UNIPOLAR LIMB LEADS
VR
VL
VF
W
aW
aG
A
W
aW
G
aG
B

CASE NO. 5 PLATE IO

ABNORMAL. Mrs.M.M.

Diagnosis: Essential Hypertension. Age 52 years.

STANDARD LIMB LEADS.

A: tracings from distal set of electrodes.

B: tracings from proximal set of electrodes.

The two sets of tracings are identical.

UNIPOLAR LIMB LEADS.

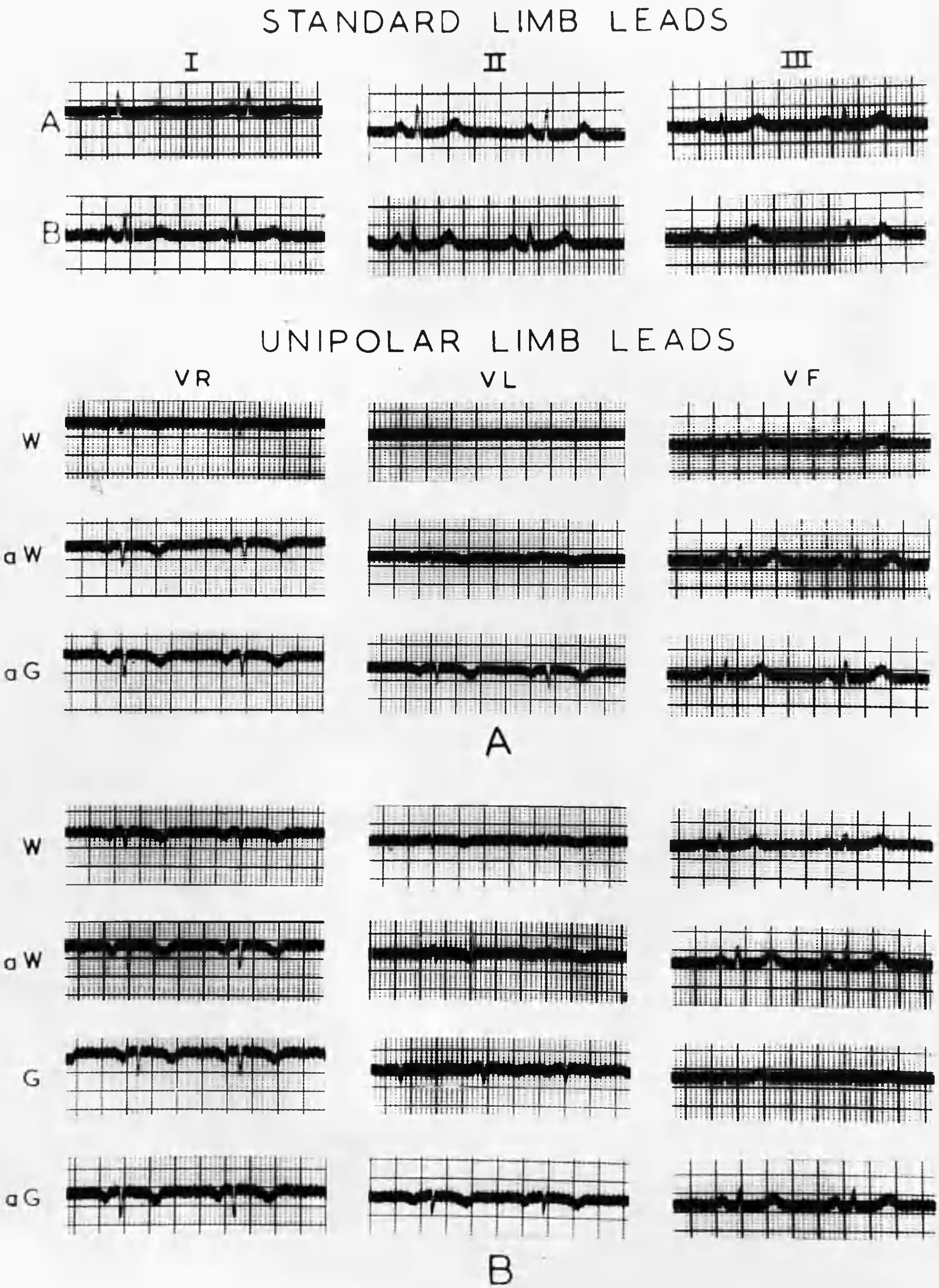
A: tracings from distal electrodes only.

The W leads are smaller in amplitude than they should be theoretically particularly in VR and VL.
The aW and aG leads resemble each other fairly closely though there are minor differences particularly in VF where there is an initial q in aW but not in aG. A consideration of the standard leads proves that this q should theoretically be present.

B: leads from proximal exploring electrodes and distal central terminal.

There is a close correspondence between the theoretical and observed values of the W and aW leads. The G and aG leads fail to show such a relationship particularly with respect to the P wave in VR, the R wave in VL and all the deflections in VF.

The aW leads in A and B are identical. The aG leads are practically identical but there are minor discrepancies,e.g. the S wave in VL is smaller in A than in B and a tiny initial q in VF appears in B but not in A.


STANDARD LIMB LEADS
I
II
III
A
B
UNIPOLAR LIMB LEADS
VR
VL
VF
W
aW
aG
A
W
aW
G
aG
B

CASE NO. 6. PLATE II.

ABNORMAL. **Miss M.C.**

Diagnosis: Post-haemorrhagic Anaemia. Age 52 years.

STANDARD LIMB LEADS.

A: tracings from distal set of electrodes.

B: tracings from proximal set of electrodes.

The two sets of tracings are identical.

UNIPOLAR LIMB LEADS.

A: tracings from distal electrodes only.

The W leads are smaller in amplitude than they should be theoretically.

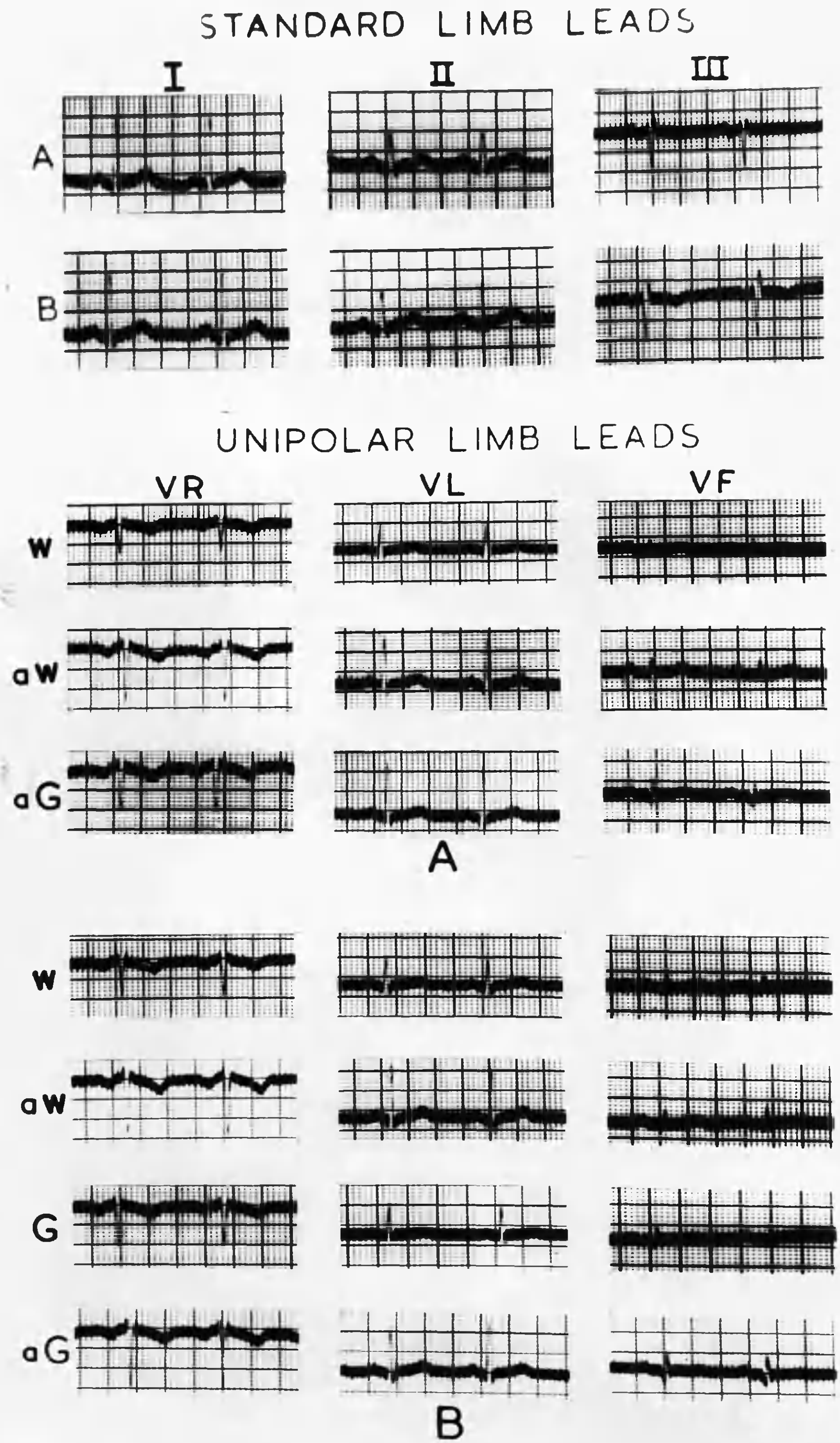
The aW and aG leads show definite differences in VL where the P and T waves are much smaller in aW than in aG and there is an rs pattern in aW but a QS pattern in aG.

B: leads from proximal exploring electrodes and distal central terminal.

A close correspondence exists between the theoretical and observed values of the W and aW leads. There is no such relationship between the G and aG leads. Differences are present between the aW and aG leads. Thus in VR all the deflections in aW are slightly smaller than those in aG; in VL the P and T waves are much smaller in aW than in aG and there is an rs pattern in aW and a QS pattern in aG.

The aW leads in A and B are identical.

The differences between the Wilson and Goldberger derivations in this case can be explained by the undue resemblance of the latter to one of the standard leads. Thus in VR the aG lead resembles an inverted lead II while in VL it resembles an inverted lead III.


STANDARD LIMB LEADS
I
II
III
A
B
UNIPOLAR LIMB LEADS
VR
VL
VF
W
aW
aG
A
W
aW
G
aG
B

CASE NO.7 PLATE I2

ABNORMAL. R.P.

Diagnosis: Obesity. Age 28 years.

STANDARD LIMB LEADS.

A: tracings from distal set of electrodes.

B: tracings from proximal set of electrodes.

Allowing for the effect of respiratory variation in lead III the two sets of tracings are practically identical.

UNIPOLAR LIMB LEADS.

A: tracings from distal electrodes only.

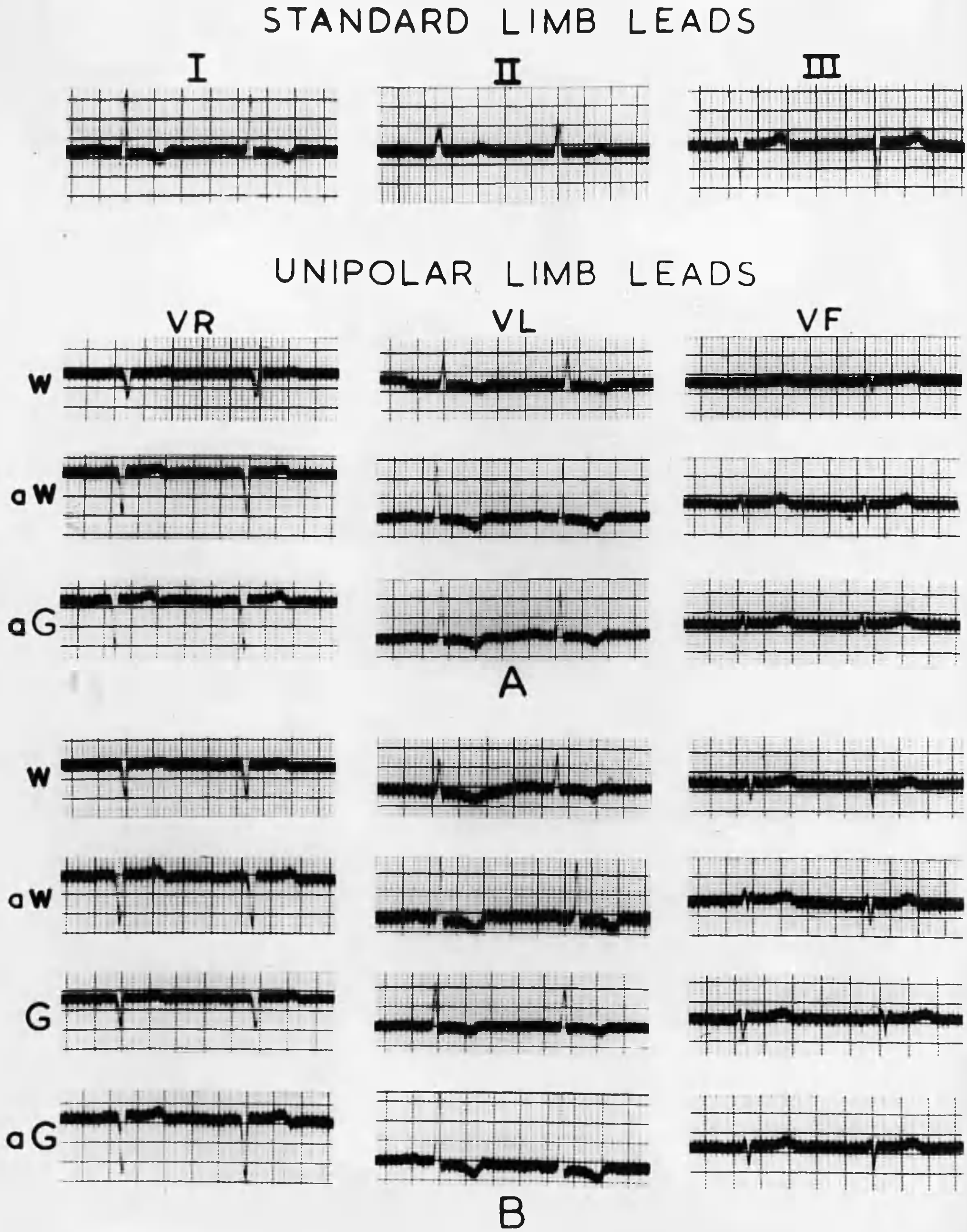
The W leads are slightly smaller in amplitude than they should be theoretically.

The aW and aG leads show differences particularly in VR where the S wave is deeper in aW than in aG and in VF where the Q wave is much more prominent in aG than in aW.

B: leads from proximal exploring electrodes and distal central terminal.

There is a close correspondence between the theoretical and observed values of the W and aW leads. The G and aG leads also have a fairly close correspondence. The aW and aG leads again show some differences especially in the Q wave of VF.

The aW leads in A and B are identical. The aG leads in A and B show differences in amplitude particularly of the QRS complexes.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
w
aW
aG
A
w
aW
G
aG
B

CASE NO.8 PLATE 15

ABNORMAL. J.S.

Diagnosis: Aortic Incompetence. Age 70 years.

STANDARD LIMB LEADS.

These were recorded from the distal electrodes only.

UNIPOLAR LIMB LEADS.

A: tracings from distal electrodes only.

The W leads are smaller in amplitude than they should be theoretically.

The aW and aG leads show differences in amplitude of the QRS complex and T wave particularly in VR and VF.

B: leads from proximal exploring electrodes and distal central terminal.

There is a close correspondence between the theoretical and observed values of the W and aW leads. There is no such relationship between the G and aG leads.

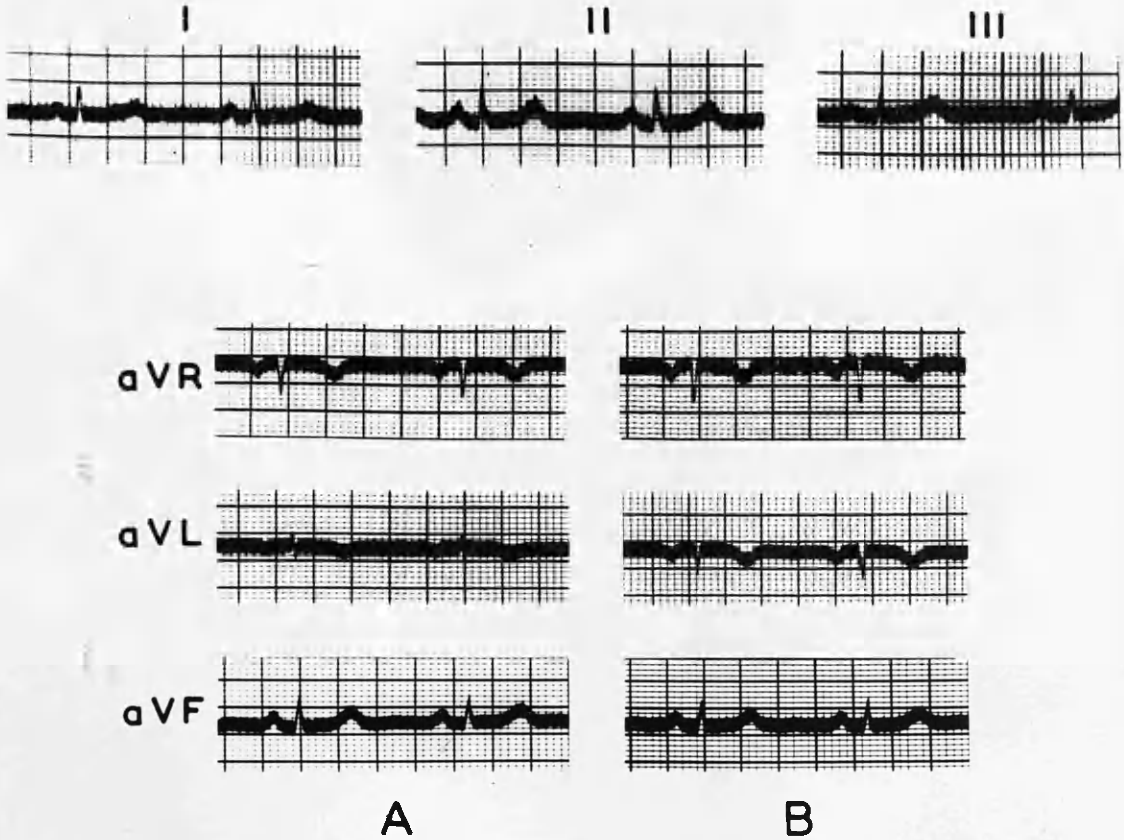
The aW leads in A and B are practically identical.

The aG leads in A and B show considerable differences in the amplitude of the QRS complexes and T waves.

PART I.

Section 5.

Plates I4 to 20.



A : WITH 5000 OHM RESISTANCES

B : WITHOUT RESISTANCES
aVR RESEMBLES LEAD II INVERTED
aVL RESEMBLES LEAD III INVERTED

LOW RESISTANCE IN LEFT LEG

CASE I.

ABNORMAL.

Miss M.C.

Diagnosis: Post-haemorrhagic Anaemia.

Age 52 years.

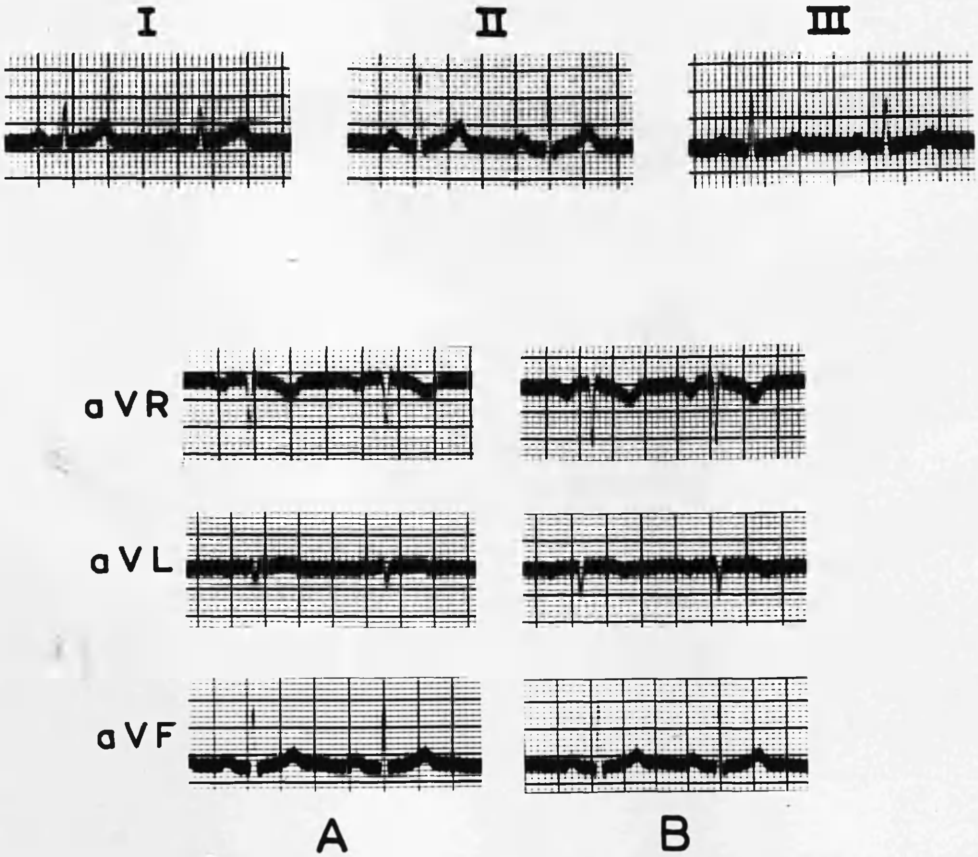
I, II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR and aVL.

aVR resembles lead II inverted.
aVL resembles lead III inverted.

These differences can be explained by a low resistance in the left leg.



A : WITH 5000 OHM RESISTANCES

B : WITHOUT RESISTANCES

aVR RESEMBLES LEAD II INVERTED

aVL RESEMBLES LEAD III INVERTED

LOW RESISTANCE IN LEFT LEG

CASE II. PLATE I5.

NORMAL. D.W.

Age 42 years.

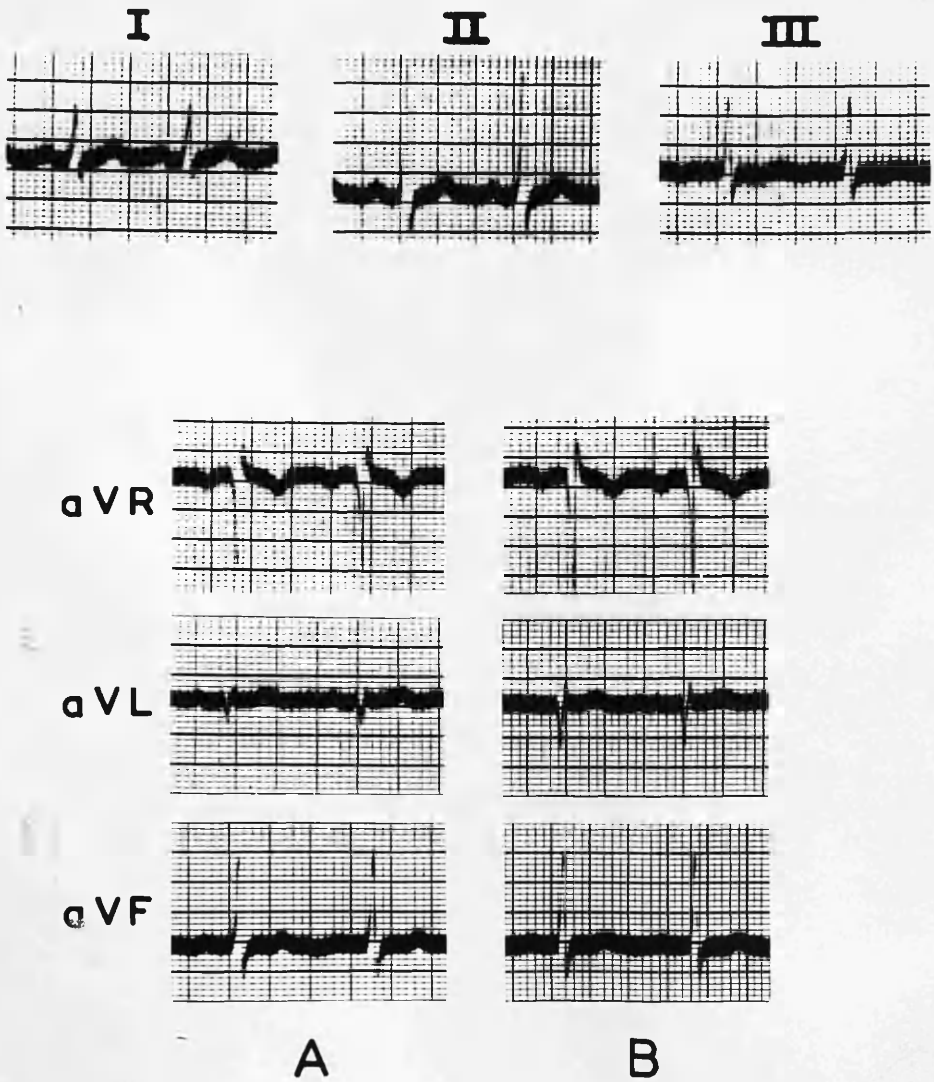
I, II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR and aVL.

aVR resembles lead II inverted.
aVL resembles lead III inverted.

These differences can be explained by a low resistance in the left leg.



A : WITH 5000 OHM RESISTANCES

B : WITHOUT RESISTANCES

aVR RESEMBLES LEAD II INVERTED

aVL RESEMBLES LEAD III INVERTED

LOW RESISTANCE IN LEFT LEG

CASE III. PLATE I6.

ABNORMAL. J.A.

Diagnosis: Rheumatic Heart Disease. Age I4 years.

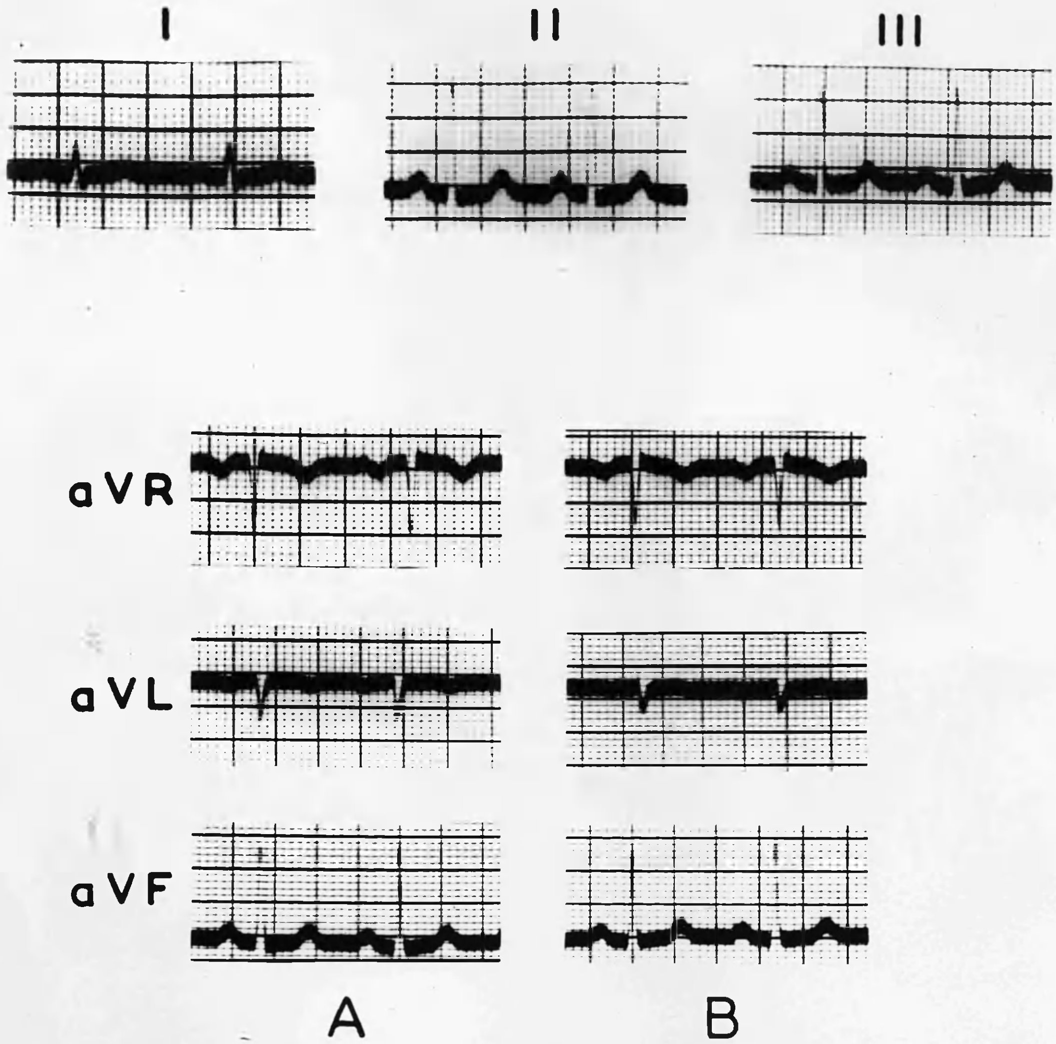
I,II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard limb leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR and aVL.

aVR resembles lead II inverted.
aVL resembles lead III inverted.

These differences can be explained by a low resistance in the left leg.



A : WITH 5000 OHM RESISTANCES

B : WITHOUT RESISTANCES

aVR RESEMBLES LEAD I INVERTED

aVL RESEMBLES LEAD I UPRIGHT

HIGH RESISTANCE IN LEFT LEG

CASE IV. PLATE I7.

NORMAL. J.T.

Age 38 years.

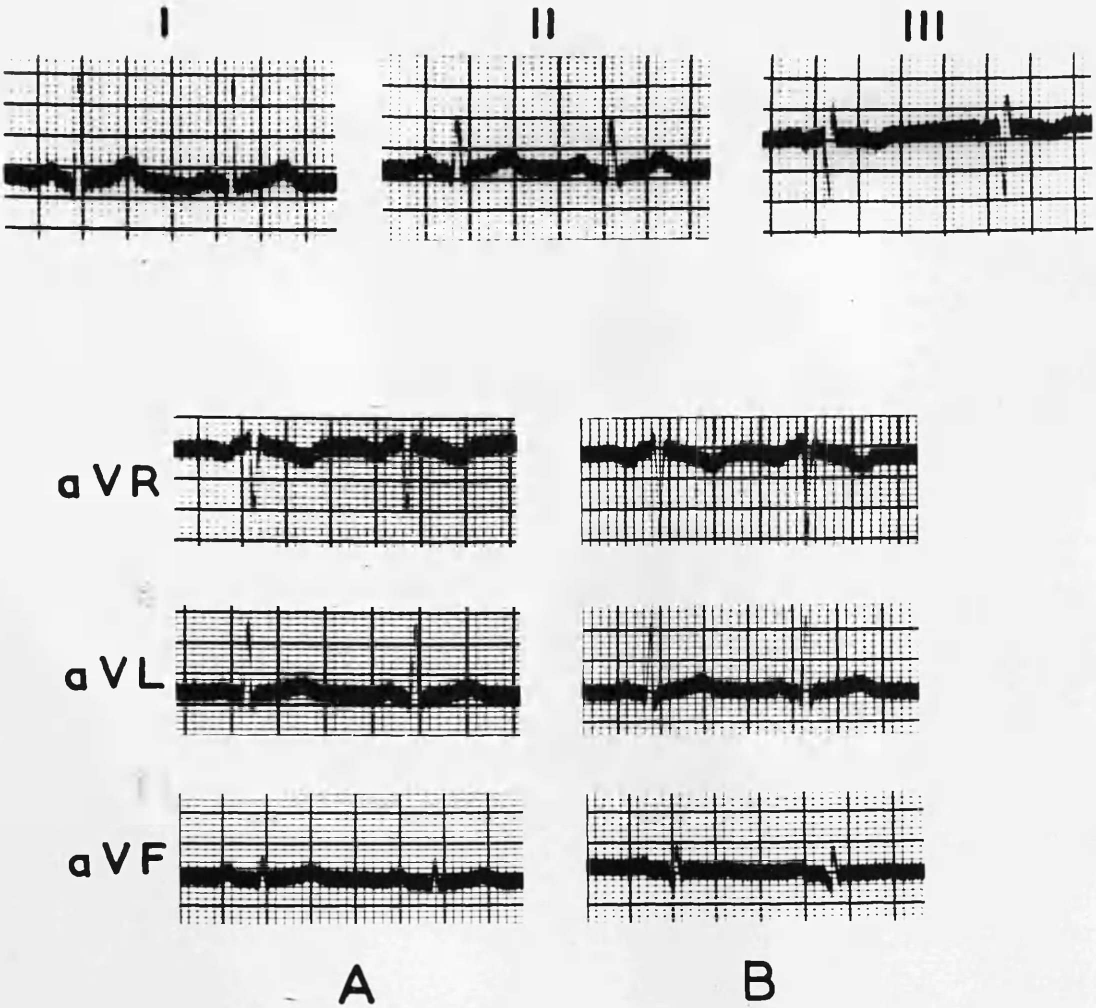
I,II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard limb leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR and aVL.

aVR resembles lead I inverted.
aVL resembles lead I upright.

These differences can be explained by a high resistance in the left leg.



A : WITH 5000 OHM RESISTANCES

B : WITHOUT RESISTANCES
aVR RESEMBLES LEAD I INVERTED
aVF RESEMBLES LEAD III UPRIGHT

LOW RESISTANCE IN LEFT ARM

CASE V. PLATE I8

ABNORMAL. R.P.

Diagnosis: Obesity. Age 28 years.

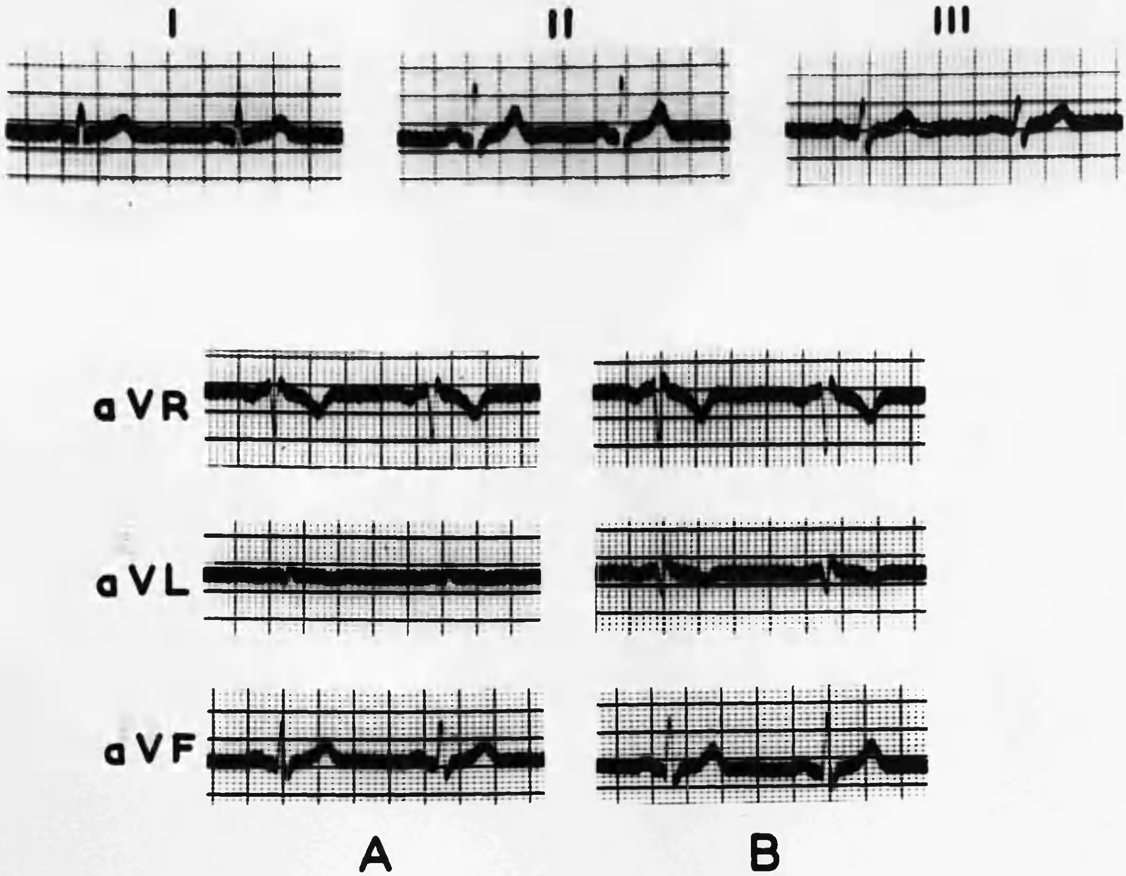
I,II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard limb leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR and aVF.

aVR resembles lead I inverted.
aVF resembles lead III upright.

These differences can be explained by a low resistance in the left arm.



A : WITH 5000 OHM RESISTANCES

B : WITHOUT RESISTANCES

aVR RESEMBLES LEAD II INVERTED

aVL RESEMBLES LEAD III INVERTED

aVF RESEMBLES LEAD II UPRIGHT

RESISTANCE IN L. ARM > R. ARM > L. LEG

CASE VI. PLATE I9

NORMAL. R.S.

Age 50 years.

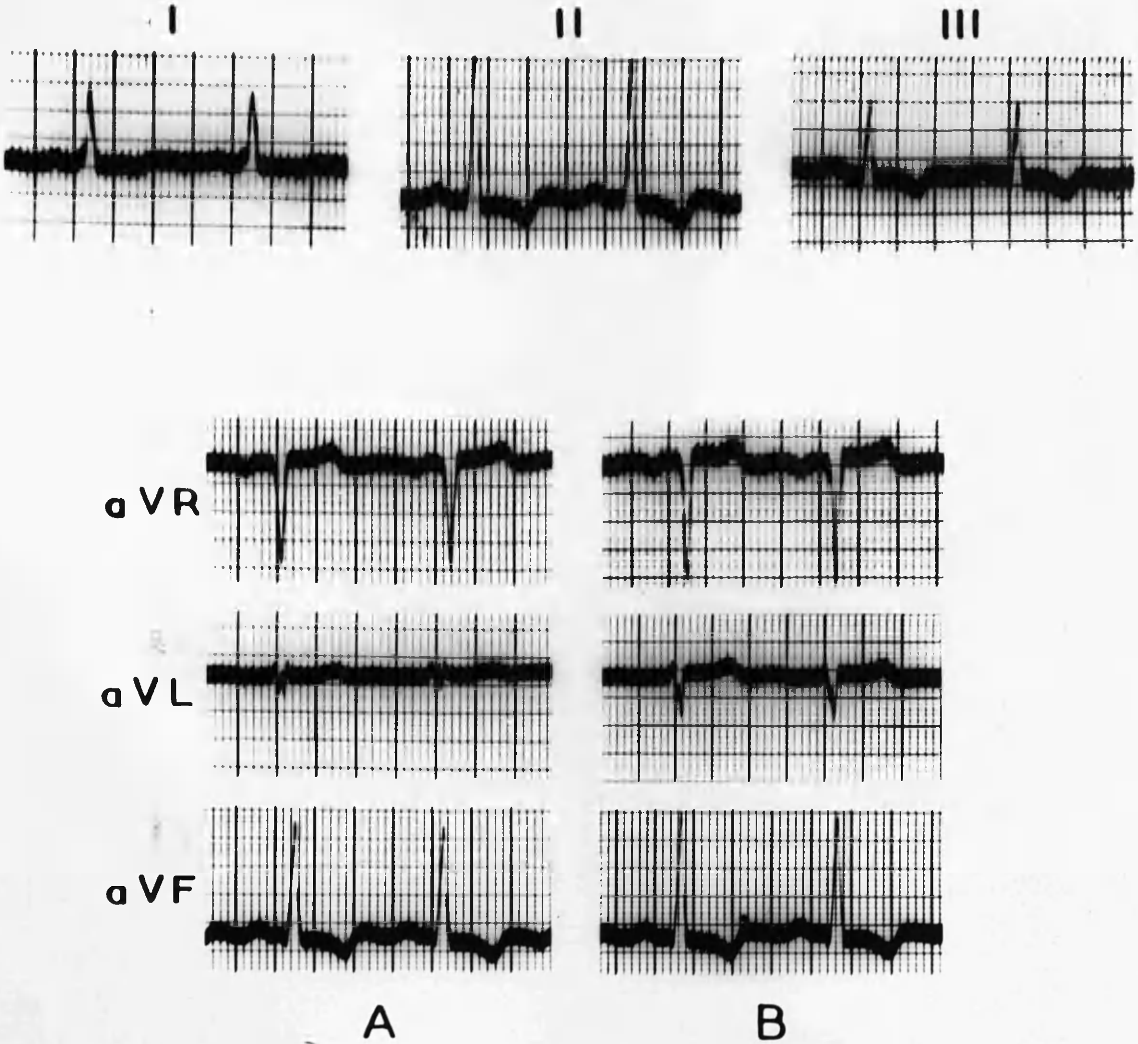
I,II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard limb leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR,aVL and aVF.

aVR resembles lead II inverted.
aVL resembles lead III inverted.
aVF resembles lead II upright.

These differences can be explained by an order of resistances such that the resistance in the left arm is greater than that in the right arm and each in turn is greater than that in the left leg.



A: WITH 5000 OHM RESISTANCES

B: WITHOUT RESISTANCES

aVR RESEMBLES LEAD II INVERTED

aVL RESEMBLES LEAD III INVERTED

aVF RESEMBLES LEAD II UPRIGHT

RESISTANCE IN L. ARM > R. ARM > L. LEG

CASE VII. PLATE 20.

ABNORMAL. G.F.

Diagnosis: Rheumatic Heart Disease. Age 4I years.

I,II and III are the three standard limb leads.

A: the augmented extremity potentials recorded with the Wilson terminal closely resemble the theoretical values calculated from the standard limb leads.

B: the augmented extremity potentials recorded with the Goldberger terminal show differences in aVR,aVL and aVF.

aVR resembles lead II inverted.
aVL resembles lead III inverted.
aVF resembles lead II upright.

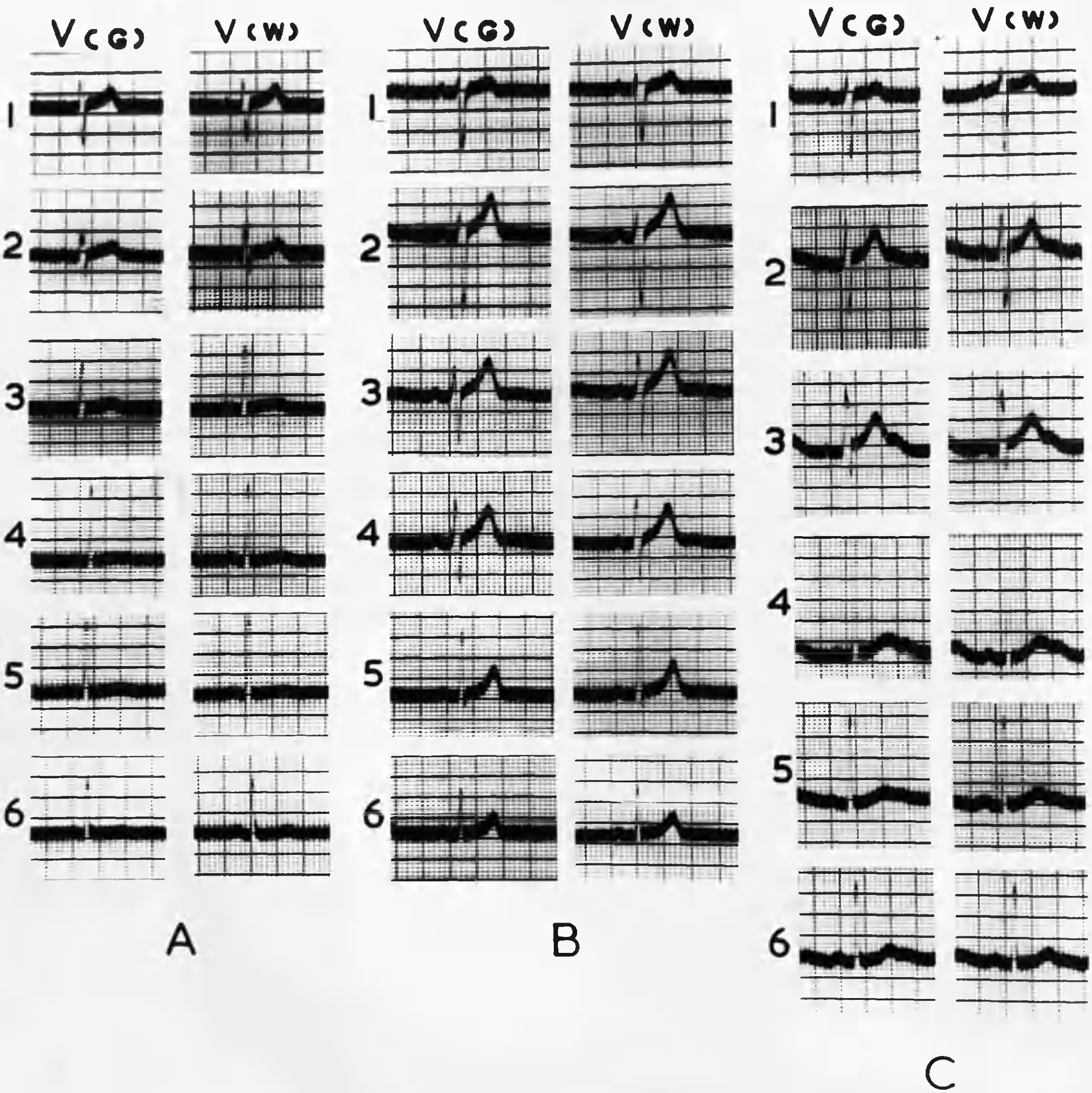
These differences can be explained by an order of resistances such that the resistance in the left arm is greater than that in the right arm and each in turn is greater than that in the left leg.

PART I.

Section 6.

Plates 2I to 23.

PRECORDIAL LEADS



CASE A. PLATE 2I.

ABNORMAL. H.McK.

Diagnosis: Chronic Myeloid Leukaemia. Age 5I years.

In this case the Wilson and Goldberger precordial leads show the following differences:

P wave: this is uniformly upright in the V(W) leads but is diphasic, negative or flat in the V(G) leads.

QRS complex: R is slightly taller and S smaller in the V(W) leads.

T wave: this is slightly taller in the V(W) leads.

CASE B.

NORMAL. D.L.

Age 3I years.

In this case the Wilson and Goldberger precordial leads show the following differences:

QRS complex: R is slightly taller and S slightly smaller in the V(W) leads.

T wave: this is slightly taller in the V(W) leads.

CASE C.

NORMAL. D.McK.

Age 38 years.

In this case there is no difference between the Wilson and Goldberger precordial leads.

CASE D.

ABNORMAL. M.H.

Diagnosis: Congenital Heart Disease. Age 14 years.

In this case the Wilson and Goldberger precordial leads show the following differences:

QRS complex: differences in the amplitude and configuration of the various waves can be seen particularly in positions 3,4 and 5. The small initial deflections tend to be absorbed in the main deflection somewhat earlier in the V(W) leads.

T wave: differences in amplitude and configuration can be seen particularly in positions 4 and 5 in the transitional zone where the wave is changing in direction.

CASE E.

ABNORMAL. G.F.

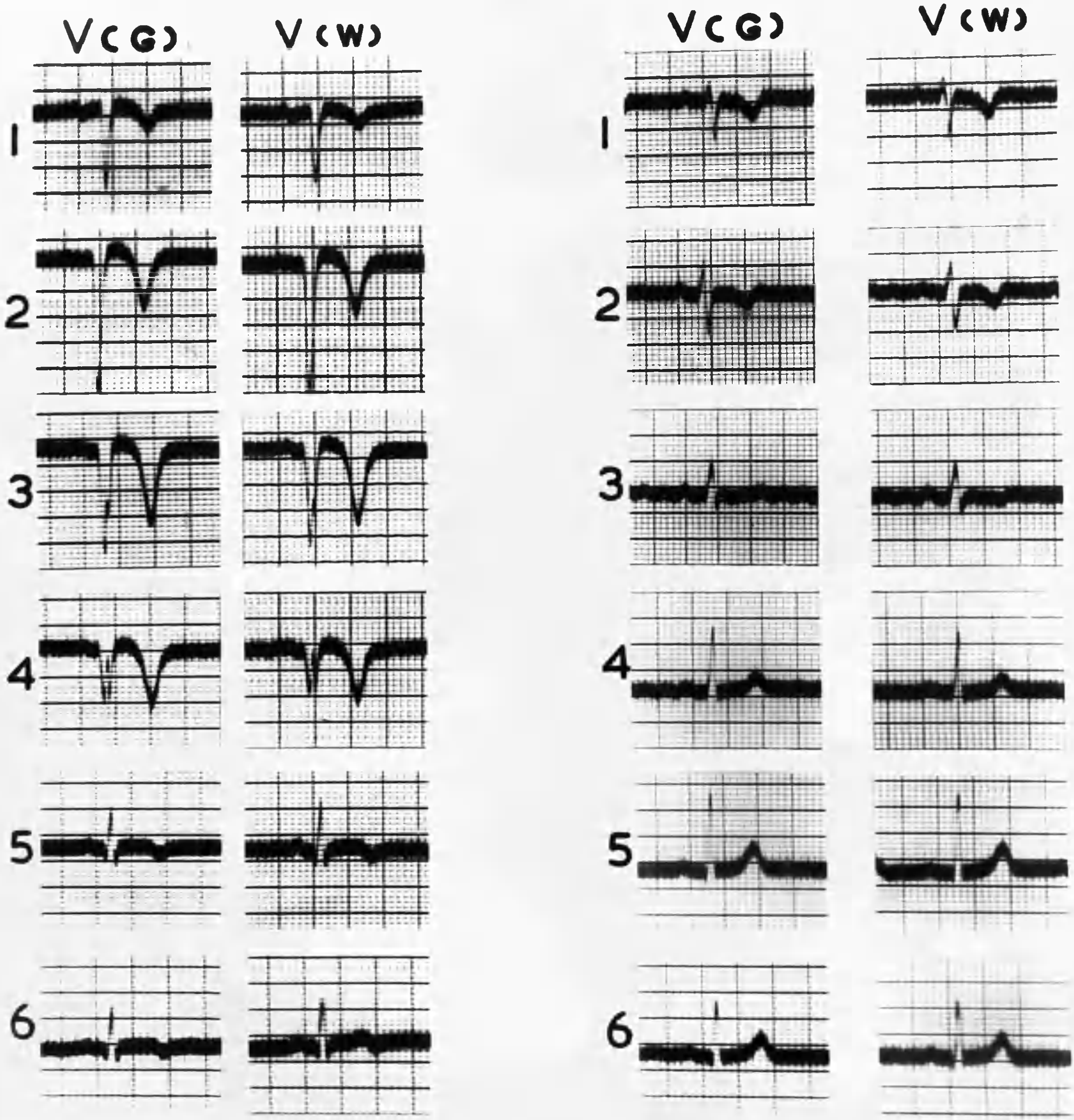
Diagnosis: Rheumatic Heart Disease. Age 41 years.

In this case the Wilson and Goldberger precordial leads show the following differences:

QRS complex: differences in amplitude and configuration can be seen particularly in positions 3 and 4 in the transitional zone and in position 7 where the smaller size of the deflection renders it more liable to obvious distortion.

T wave: slight differences in amplitude are present. In positions 1 and 2, T in the V(W) leads is more positive while from position 3 onwards it tends to be less positive than in the V(G) leads. This is most apparent in position 7.

PRECORDIAL LEADS



F   G

CASE F.

ABNORMAL. J.Y.

Diagnosis: Myocardial Infarction: (anterior) Age 5I years.

In this case the Wilson and Goldberger precordial leads show the following differences:

P wave: this is more positive in the V(W) leads.

QRS complex: this is more positive in the V(W) leads.

T wave: this is more positive in the V(W) leads. This is particularly obvious in position 6 at the edge of the infarct where the T wave is changing its direction.

CASE G.

ABNORMAL. Mrs.C.P.

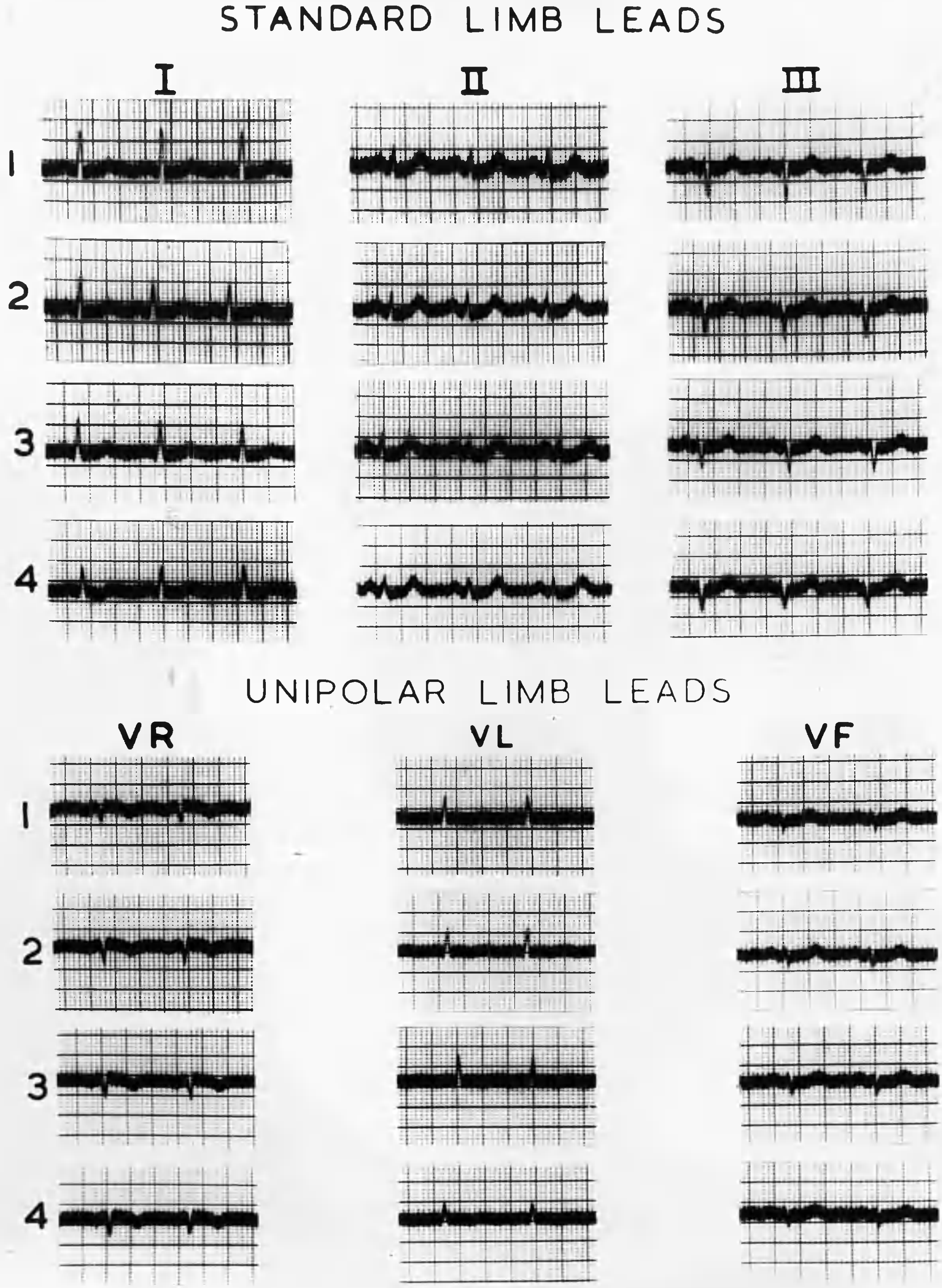
Diagnosis: Pulmonary Tuberculosis. Age 29 years.

In this case the only difference between the Wilson and Goldberger precordial leads is in the T wave. It is slightly less positive in the V(W) leads than in the V(G) leads. This is best seen in position 3 in the transition zone where the T wave is changing its direction: it is upright in the V(G) lead and inverted in the V(W) lead.

PART I.

Section 7.

Plates 24 to 28.


STANDARD LIMB LEADS
I
II
III
1
2
3
4
UNIPOLAR LIMB LEADS
VR
VL
VF
1
2
3
4

CASE NO. I PLATE 34.

Effect of External Resistances. A.W.

Diagnosis: Myocardial Infarction (Anterior) Age 54 years.

STANDARD LIMB LEADS.

The four sets of tracings were taken as follows:

I. No external resistances.

2. 5000 ohms in each lead wire.

3. 10000 ohms in each lead wire.

4. 20000 ohms in each lead wire.

The tracings in series 3 and 4 show progressive slurring and decrease in amplitude of the deflections.

UNIPOLAR LIMB LEADS.

These were taken with a three point central terminal and a common electrode for the exploring and terminal connections. The external resistances in the branches of the central terminal were as follows:

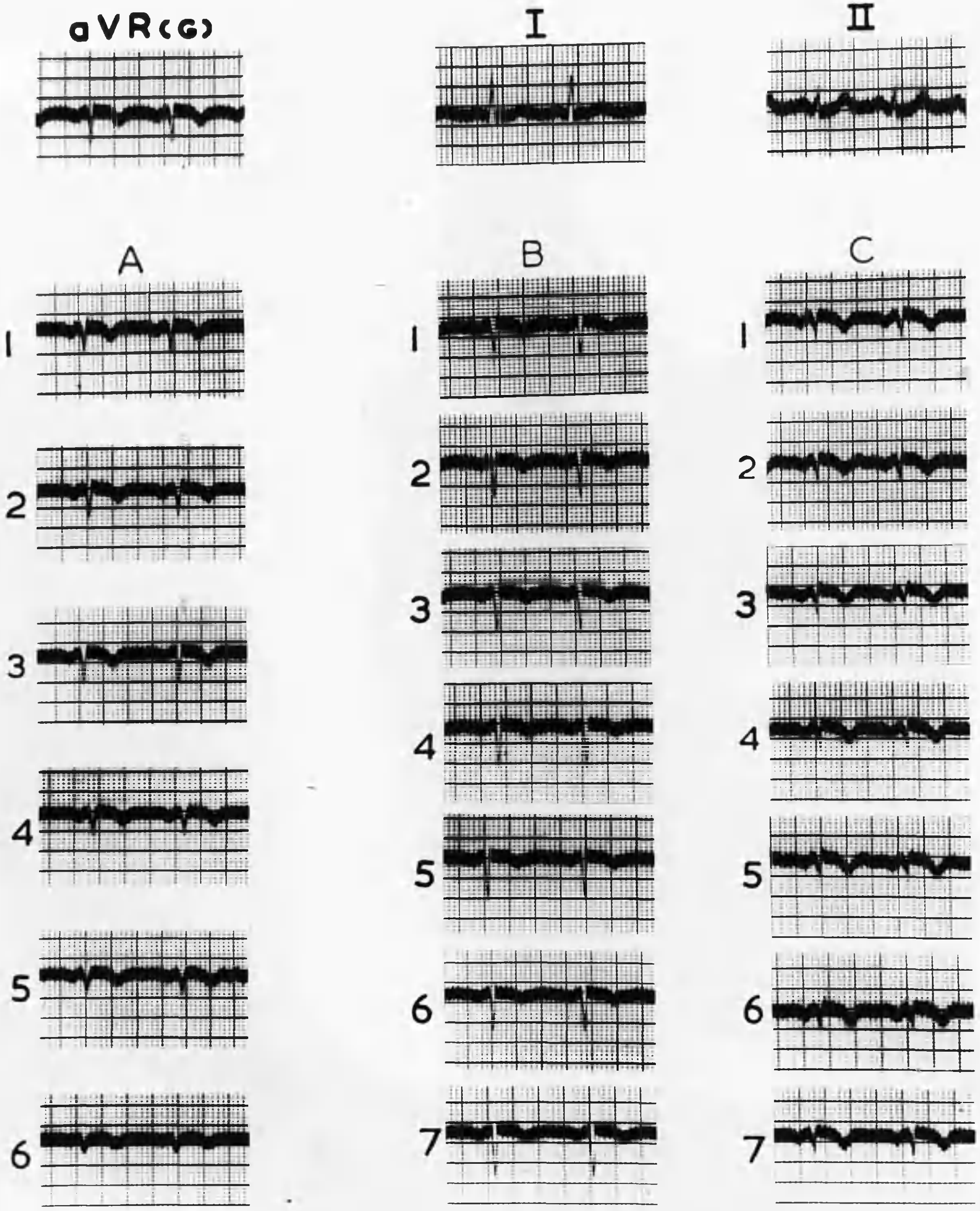
I. 5000 ohms in each branch.

2. 10000 ohms in each branch.

3. 20000 ohms in each branch.

4. 50000 ohms in each branch.

The tracings in series I,2 and 3 are identical. Series 4 shows slurring and decrease in amplitude of the deflections.



aVR(G)
I
II
A
B
C
1
2
3
4
5
6
1
2
3
4
5
6
7
1
2
3
4
5
6
7

Effect of External Resistances.

Lead aVR(G), Lead I and Lead II were controls.

Series A.

The connections were for Lead aVR with equal resistances in the two branches of the central terminal as follows:

I. 5000 ohms in each branch.
2. 10000 ohms in each branch.
3. 20000 ohms in each branch.
4. 50000 ohms in each branch.
5. 100000 ohms in each branch.
6. 200000 ohms in each branch.

The tracings 1, 2 and 3 are identical and closely resemble aVR(G). Tracings 4, 5 and 6 show progressive slurring and decrease in amplitude of the deflections.

Series B.

The connections were for Lead aVR with no resistance in the left arm wire and resistances in the left leg wire as follows:

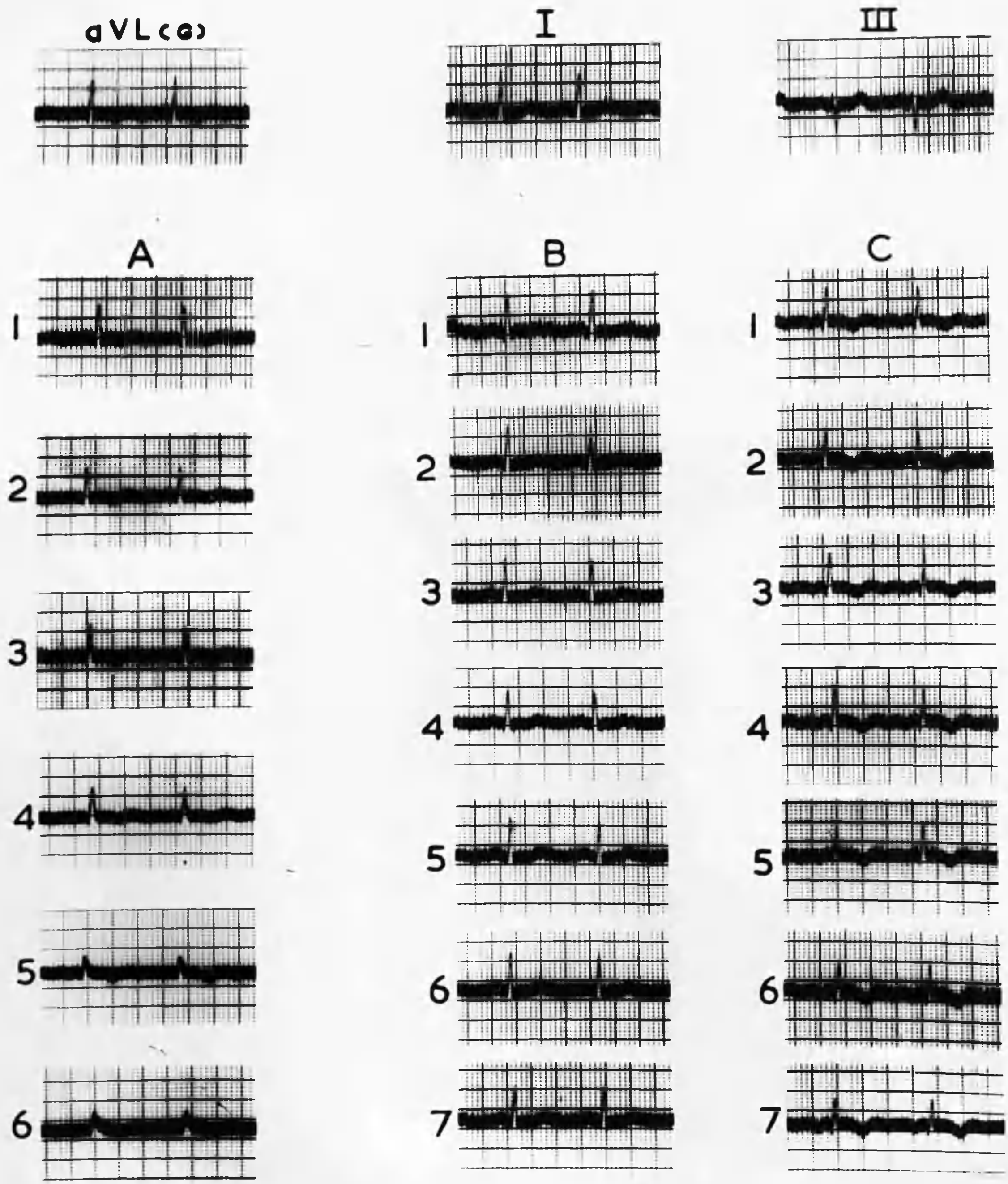
I. 5000 ohms.
2. 10000 ohms.
3. 20000 ohms.
4. 50000 ohms.
5. 100000 ohms.
6. 200000 ohms.
7. I megohm.

All the tracings are identical with an inverted Lead I.

Series C.

The procedure was similar to that for Series B with no resistance in the left leg wire and increasing resistances added to the left arm wire.

All the tracings are identical with an inverted Lead II.


aVL(a)
I
III
A
B
C
1
2
3
4
5
6
7

Effect of External Resistances.

Lead aVL(G), Lead I and Lead III were controls.

Series A.

The connections were for Lead aVL with equal resistances in the two branches of the central terminal as already described.

The tracings 1,2 and 3 are identical and closely resemble aVL(G). Tracings 4,5 and 6 show progressive slurring and decrease in amplitude of the deflections.

Series B.

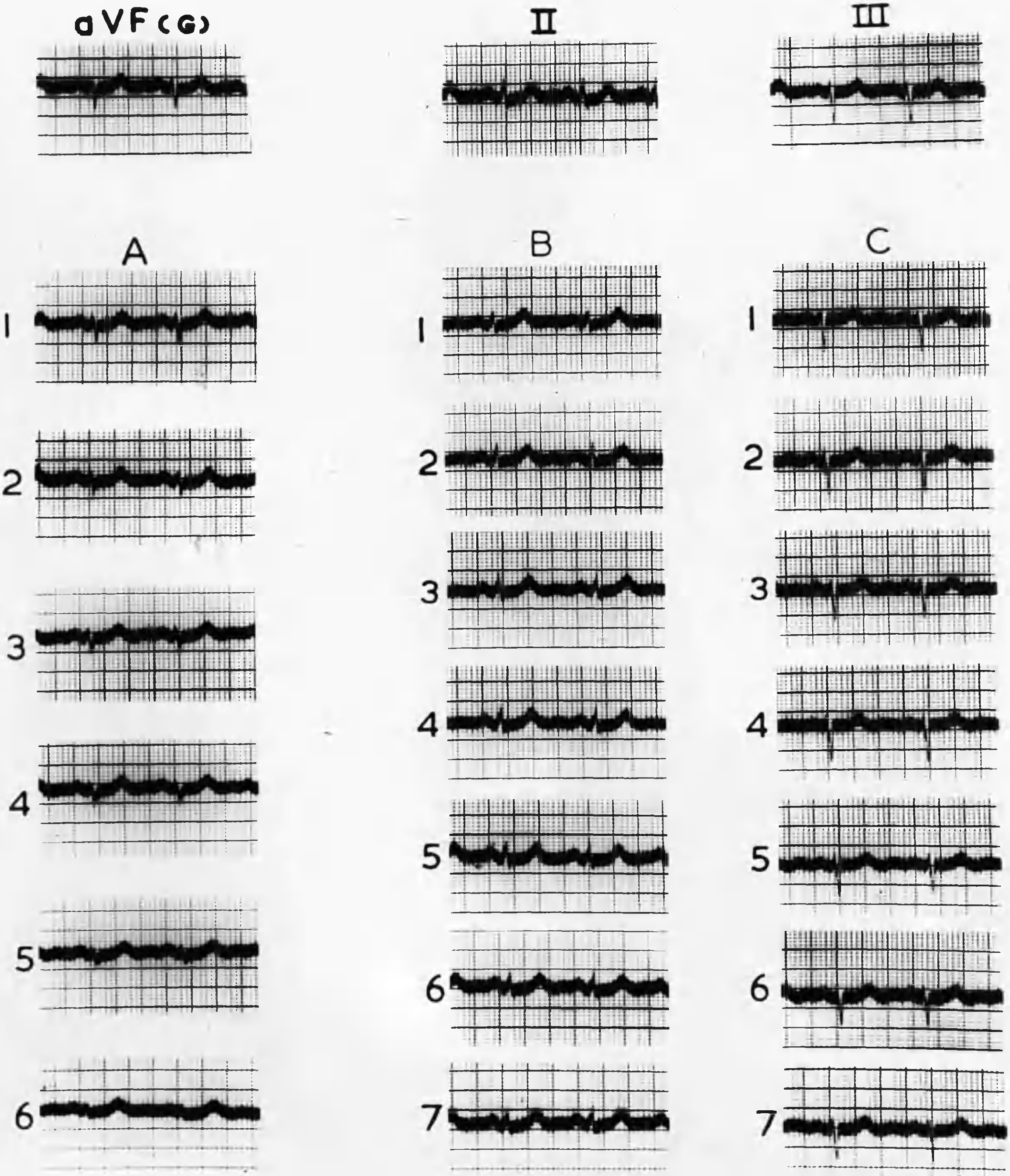
The connections were for Lead aVL with no resistance in the right arm wire and increasing resistances in the left leg as already described.

All the tracings are identical with an upright Lead I.

Series C.

The procedure was similar to that for Series B with no resistance in the left leg wire and increasing resistances added to the right arm wire.

All the tracings are identical with an inverted Lead III.


aVF (G)
II
III
A
B
C
1
2
3
4
5
6
7

Effect of External Resistances.

Lead aVF(G), Lead II and Lead III were controls.

Series A.

The connections were for Lead aVF with equal resistances in the two branches of the central terminal as already described.

The tracings 1,2 and 3 are identical and closely resemble aVF(G). Tracings 4,5 and 6 show progressive slurring and decrease in amplitude of the deflections.

Series B.

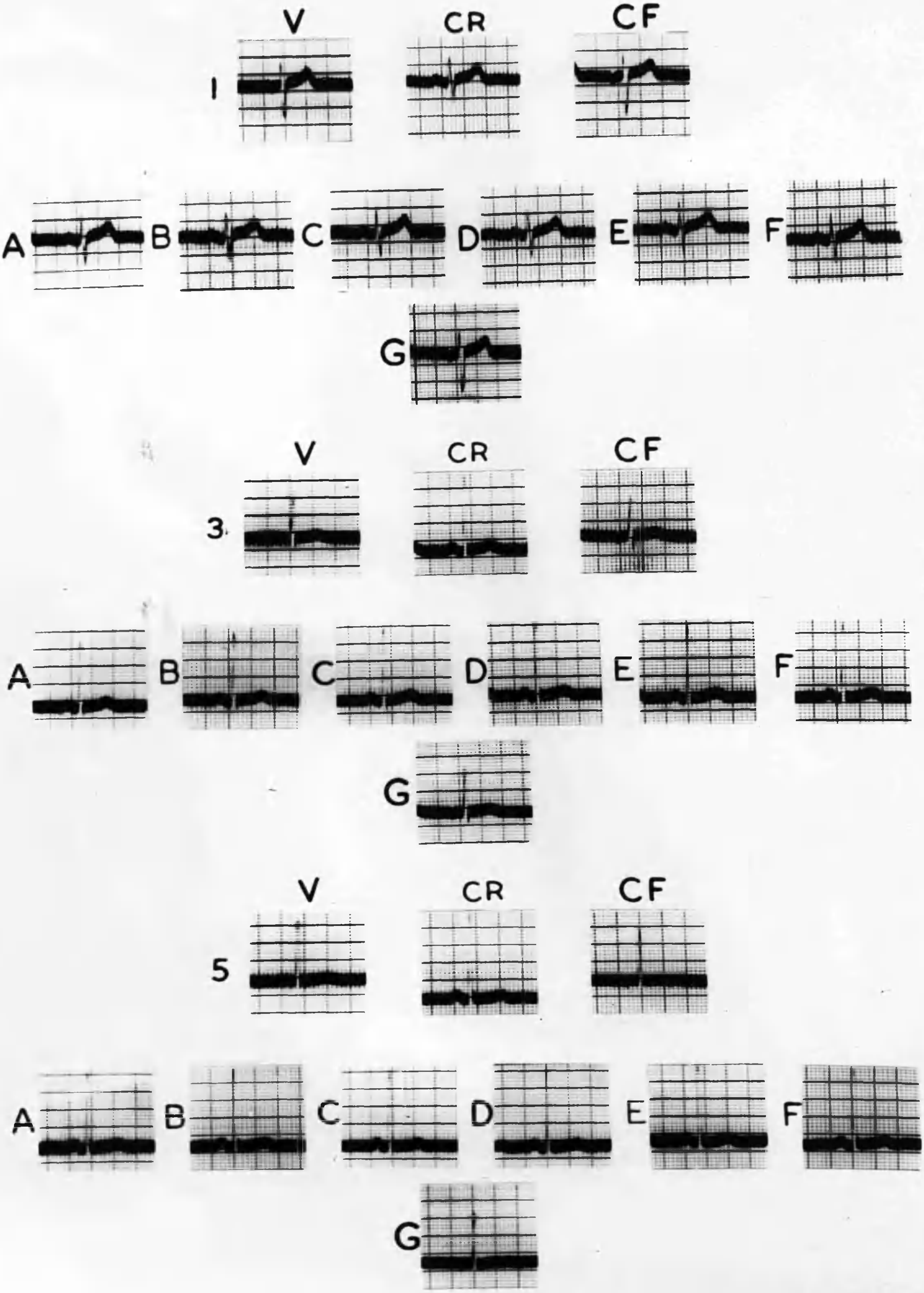
The connections were for Lead aVF with no resistance in the right arm wire and increasing resistances in the left arm wire as already described.

All the tracings are identical with an upright Lead II.

Series C.

The procedure was similar to that for Series B with no resistance in the left arm wire and increasing resistances in the right arm wire.

All the tracings are identical with an upright Lead III.


V
CR
CF
1
A
B
C
D
E
F
G
V
CR
CF
3
A
B
C
D
E
F
G
V
CR
CF
5
A
B
C
D
E
F
G

Effect of External Resistances on the Precordial Leads.

H.McK.

Age 51 years.

Position I.

Leads V, CR and CF were controls, V being recorded with a Goldberger central terminal.

Tracings A to F were obtained by keeping the right arm wire of the terminal at no resistance and adding equal resistances to the left arm and left leg wires as follows:

5000 ohms(A): 10000 ohms(B): 20000 ohms(C): 100000 ohms(D): 500000 ohms(E): 1 megohm(F).

All the tracings are identical with CR.

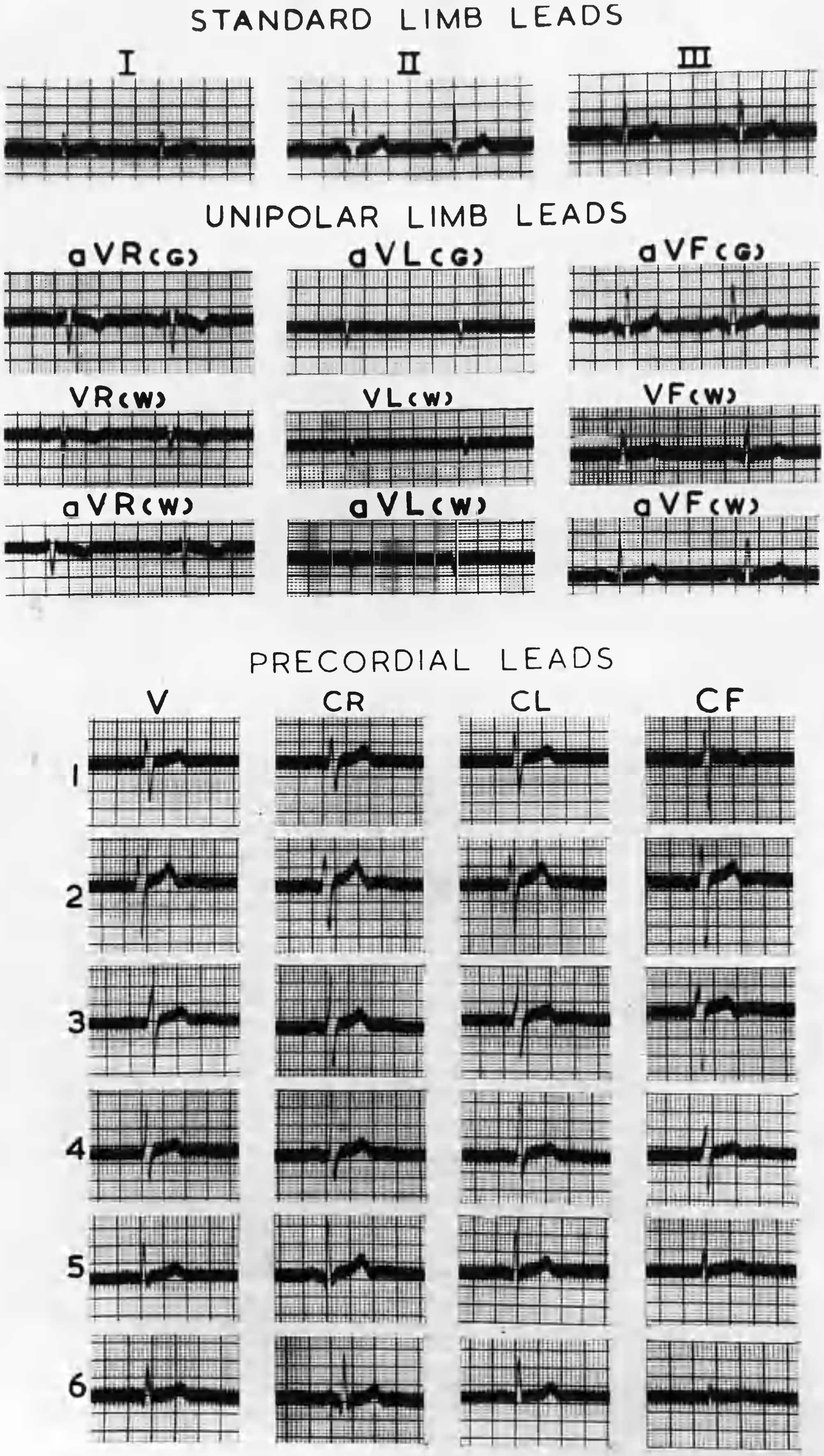
Tracing G was obtained as follows: the left leg wire of the terminal was kept at no resistance and equal resistances of 5000 ohms were added to the right arm and left arm wires.

The tracing is identical with CF.

Positions 3 and 5.

Tracings were taken in the same way as for Position I.

Again it can be seen that the V lead is converted to the corresponding CR or CF lead.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. I

PLATE 29.

NORMAL.

T.S.

Age 29 years.

STANDARD LIMB LEADS.

The standard limb leads show a tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and T waves and a QS pattern.

The VF leads have upright P and T waves and a qRs pattern.

Electrically the heart is vertical.

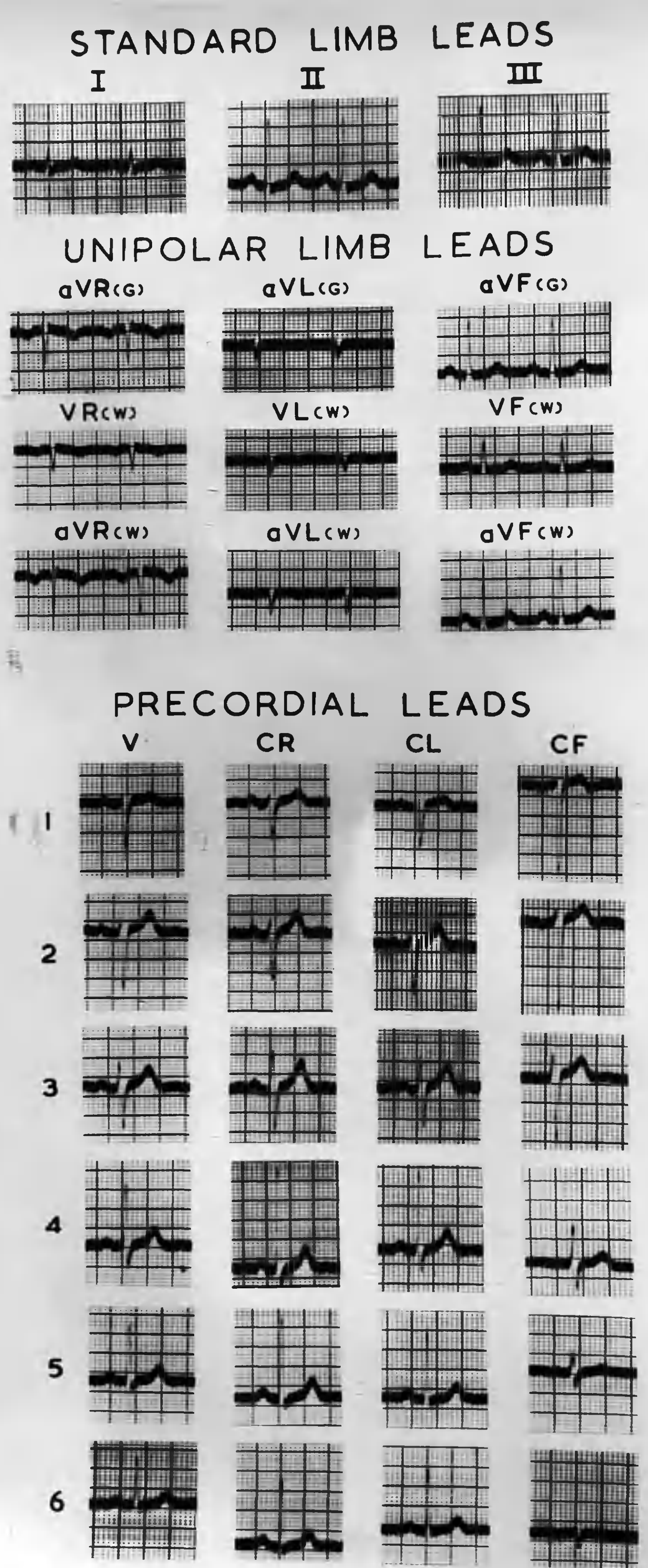
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 2 PLATE 30.

NORMAL. J.T.

Age 38 years.

STANDARD LIMB LEADS.
These show R.A.D.

UNIPOLAR LIMB LEADS.
The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have low inverted P and T waves and a QS pattern.

The VF leads have upright P and T waves and a qR pattern.

Electrically the heart is vertical.

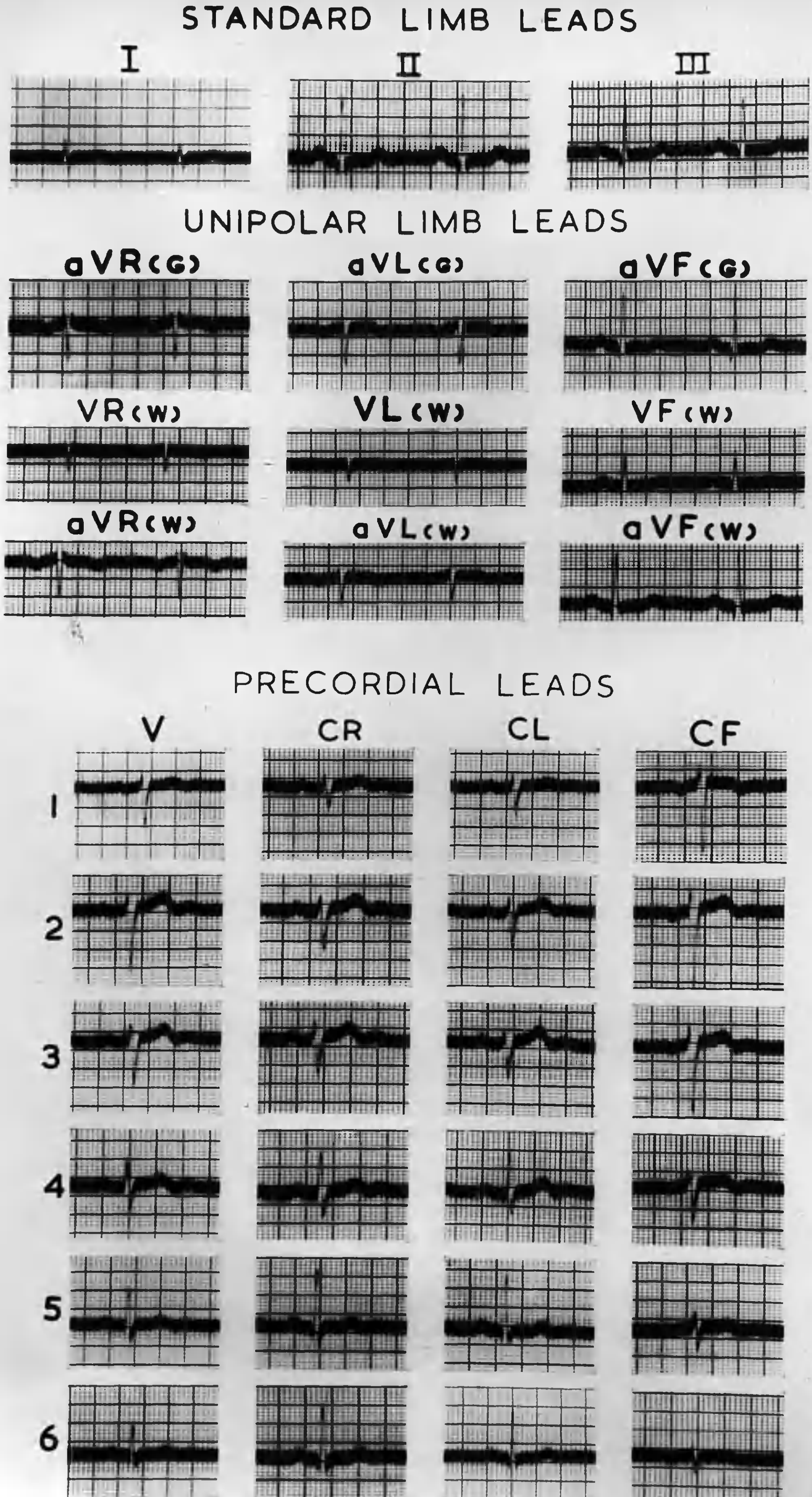
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions 1, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.3 PLATE 3I.

NORMAL. W.McC.

Age 45 years.

STANDARD LIMB LEADS.

These show R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have inverted P waves, practically flat T waves and an rS pattern.

The VF leads have upright P and T waves and a qR pattern.

Electrically the heart is vertical.

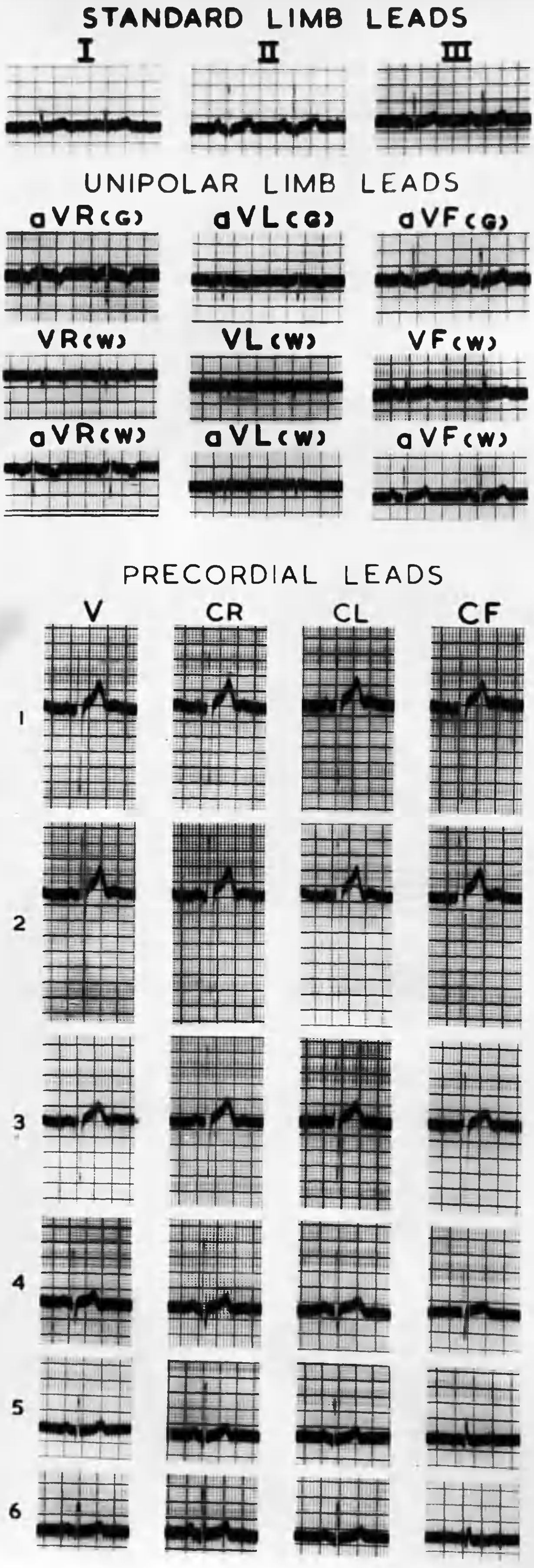
PRECORDIAL LEADS.

P wave: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

-T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences particularly in the QRS complexes are obvious in all six positions.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.4 PLATE 32

NORMAL. T.J.

Age 20 years.

STANDARD LIMB LEADS.

These show a tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have shallow inverted P and T waves and an rSr' pattern.

The VF leads have upright P and T waves and a qRs pattern.

Electrically the heart is vertical.

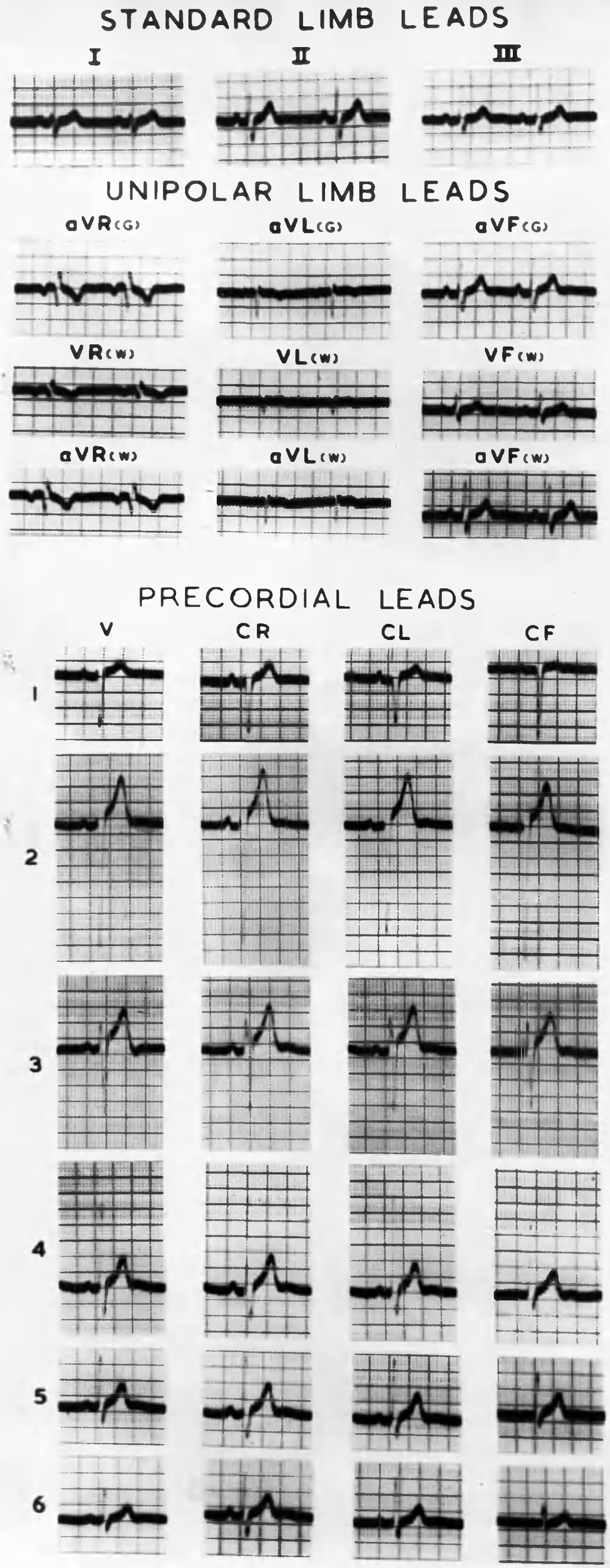
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 5 PLATE 33.

NORMAL. B.K.

Age 2I years.

STANDARD LIMB LEADS.

These show prominent S waves in all leads.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a QR pattern.

The VL leads have practically flat P and slightly inverted T waves and an rSr' pattern.

The VF leads have upright P and T waves and an RS pattern.

Electrically the heart is vertical.

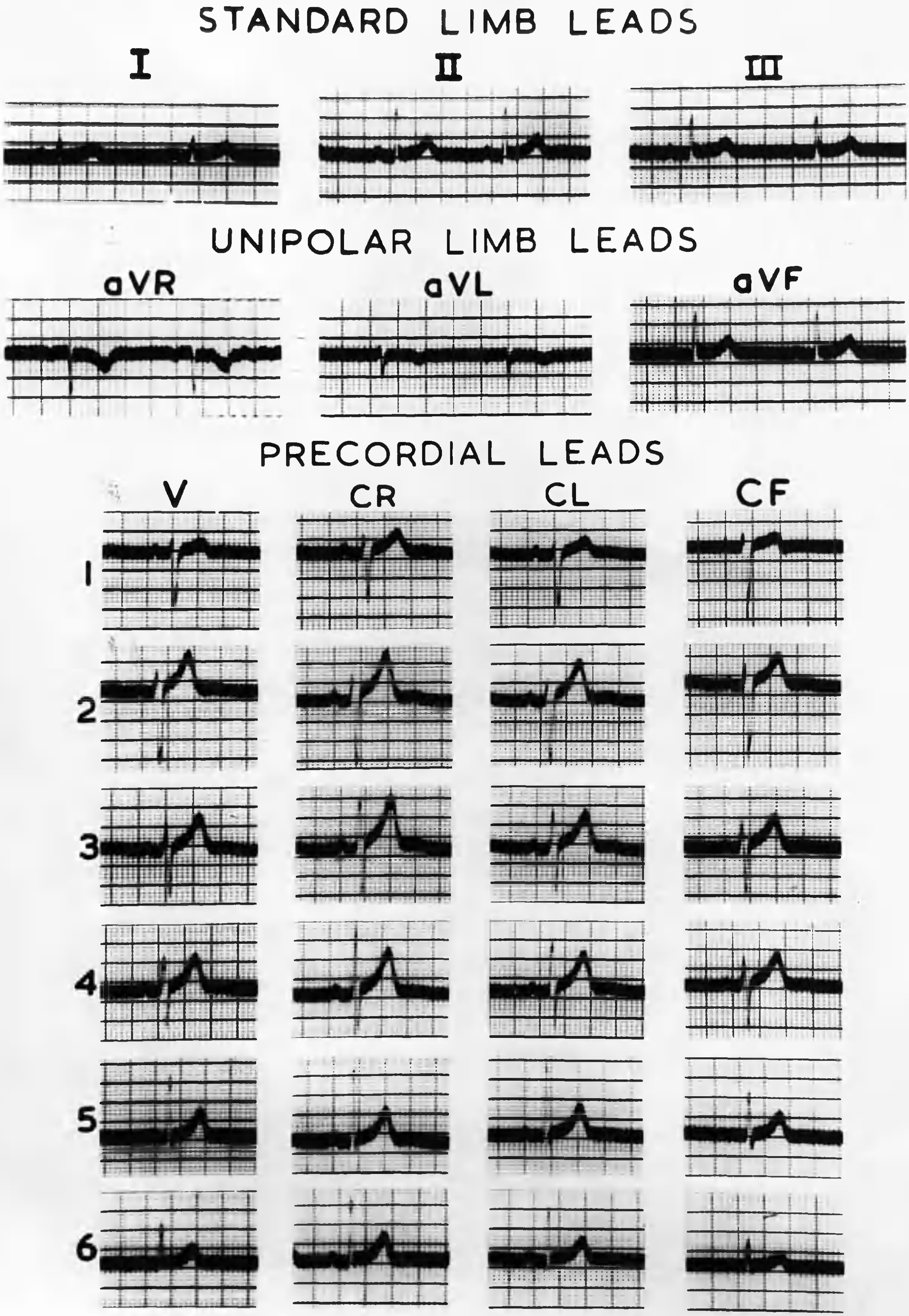
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CL and CR leads, least positive in the CF leads and intermediate in the V leads. The S wave in leads over the left precordium is deepest in CR and least in CF, due to the prominent R and S in VR and VF respectively.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.6 PLATE 34.

NORMAL. D.L.

Age 3I years.

STANDARD LIMB LEADS.

These show a tendency to R.A.D.

UNIPOLAR LIMB LEADS.

Lead aVR has inverted P and T waves and an rSr' pattern.

Lead aVL has slightly inverted P and T waves and an rS pattern.

Lead aVF has upright P and T waves and a qR pattern.

Electrically the heart is vertical.

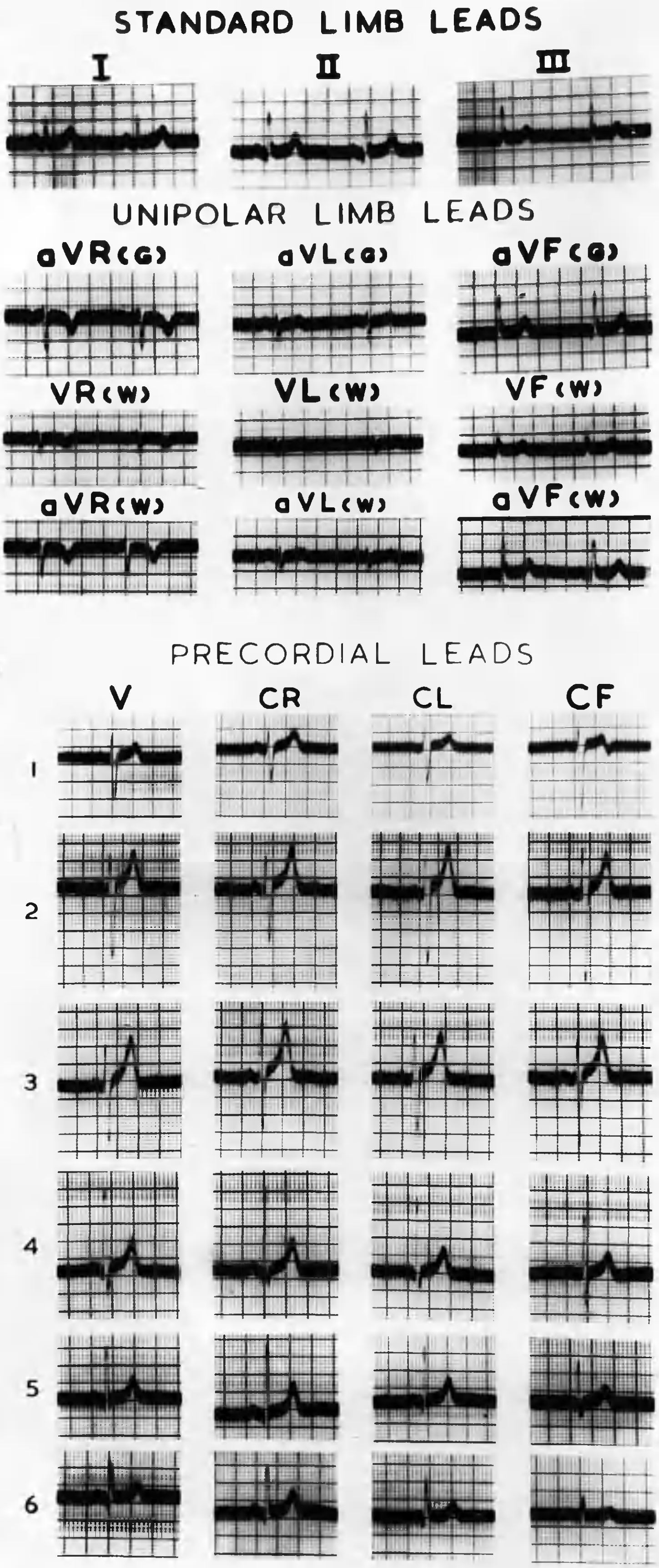
PRECORDIAL LEADS.

P wave: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads. Note the absence of a Q wave in CF5 and 6 due to the q in aVF.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.7 PLATE 35.

NORMAL. R.F.

Age 58 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rS pattern.

The VL leads have low upright P and T waves and an rS pattern.

The VF leads have practically flat P waves, upright T waves and a qR pattern.

Electrically the heart is vertical.

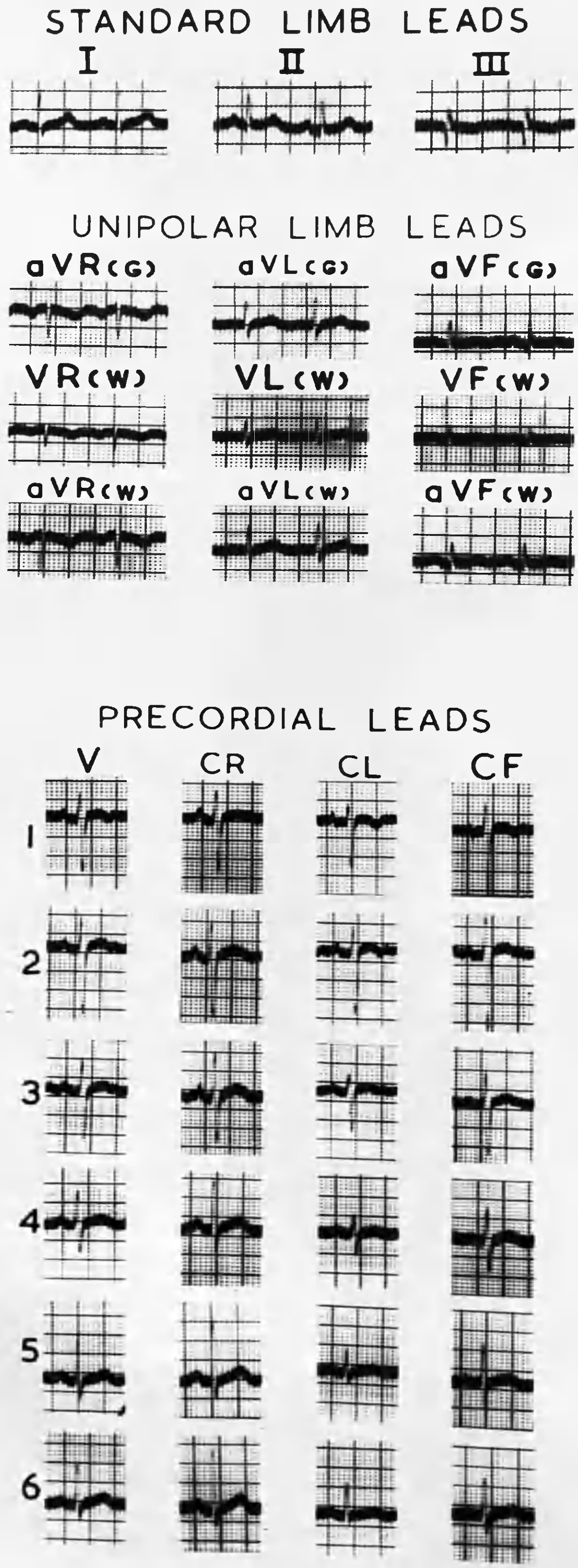
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 2 and 6.



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.8 PLATE 36.

NORMAL.

Miss H.F.

Age I5 years.

STANDARD LIMB LEADS.

These show a deep Q and shallow inverted T waves in lead III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and upright T waves and an Rs pattern

The VF leads have upright P and low upright T waves and a qR pattern.

The deep Q in lead III is due mainly to the tall R in the VL lead.

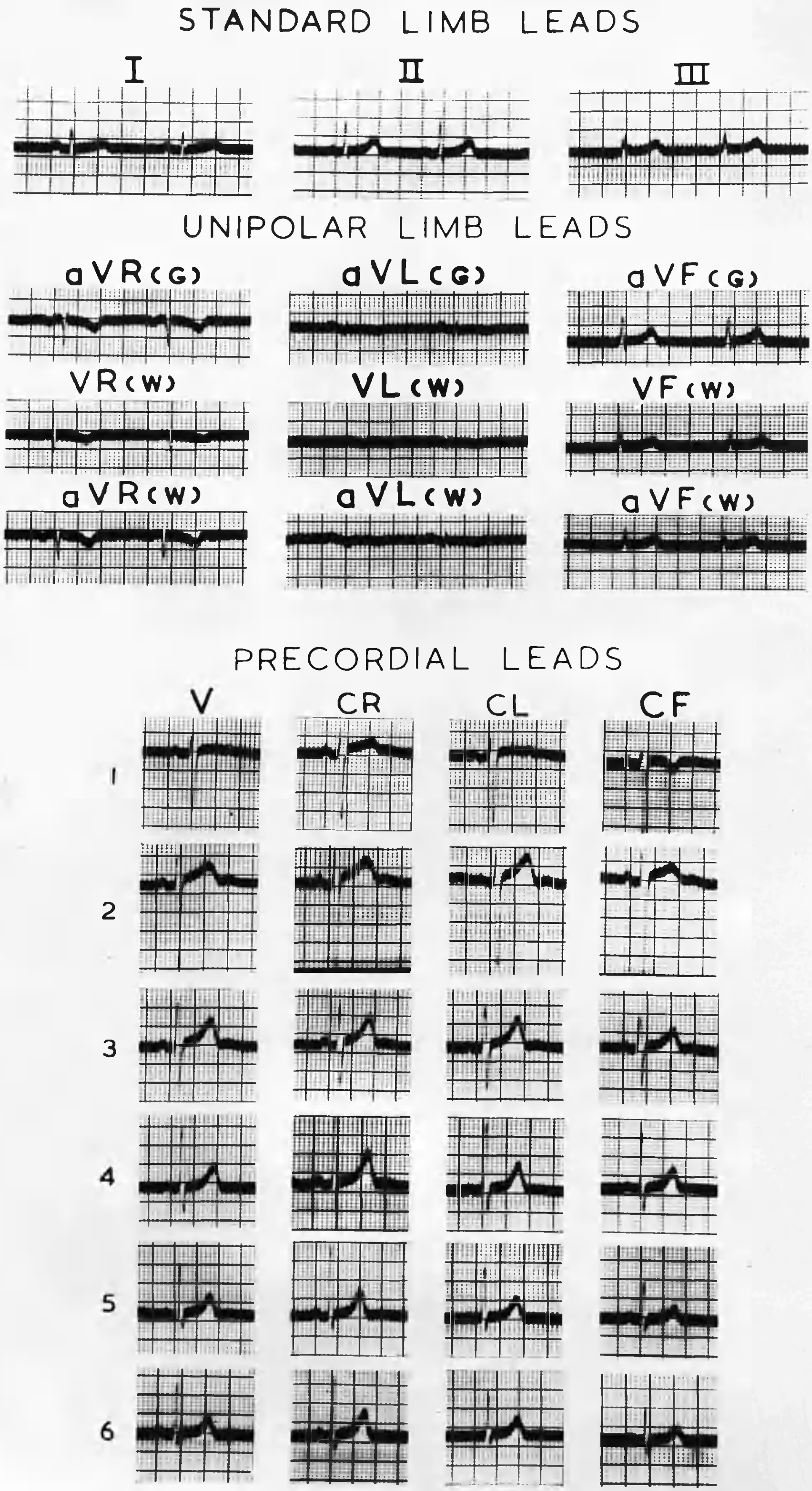
Electrically the heart is in an indeterminate position, probably vertical with moderate clockwise rotation and forward rotation of the apex.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in th CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads. The R in CF is taller than that in CL due to the q in VF; the S in CL is smaller than that in CF, CR and V due to the s in VL.

T wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR (G)
aVL (G)
aVF (G)
VR (W)
VL (W)
VF (W)
aVR (W)
aVL (W)
aVF (W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 9 PLATE 37

NORMAL. J.McG.

Age I6 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have upright P and shallow inverted T waves and a small vibratory qrs pattern.

The VF leads have flat P and upright T waves and an Rs pattern.

Electrically the heart is semi-vertical.

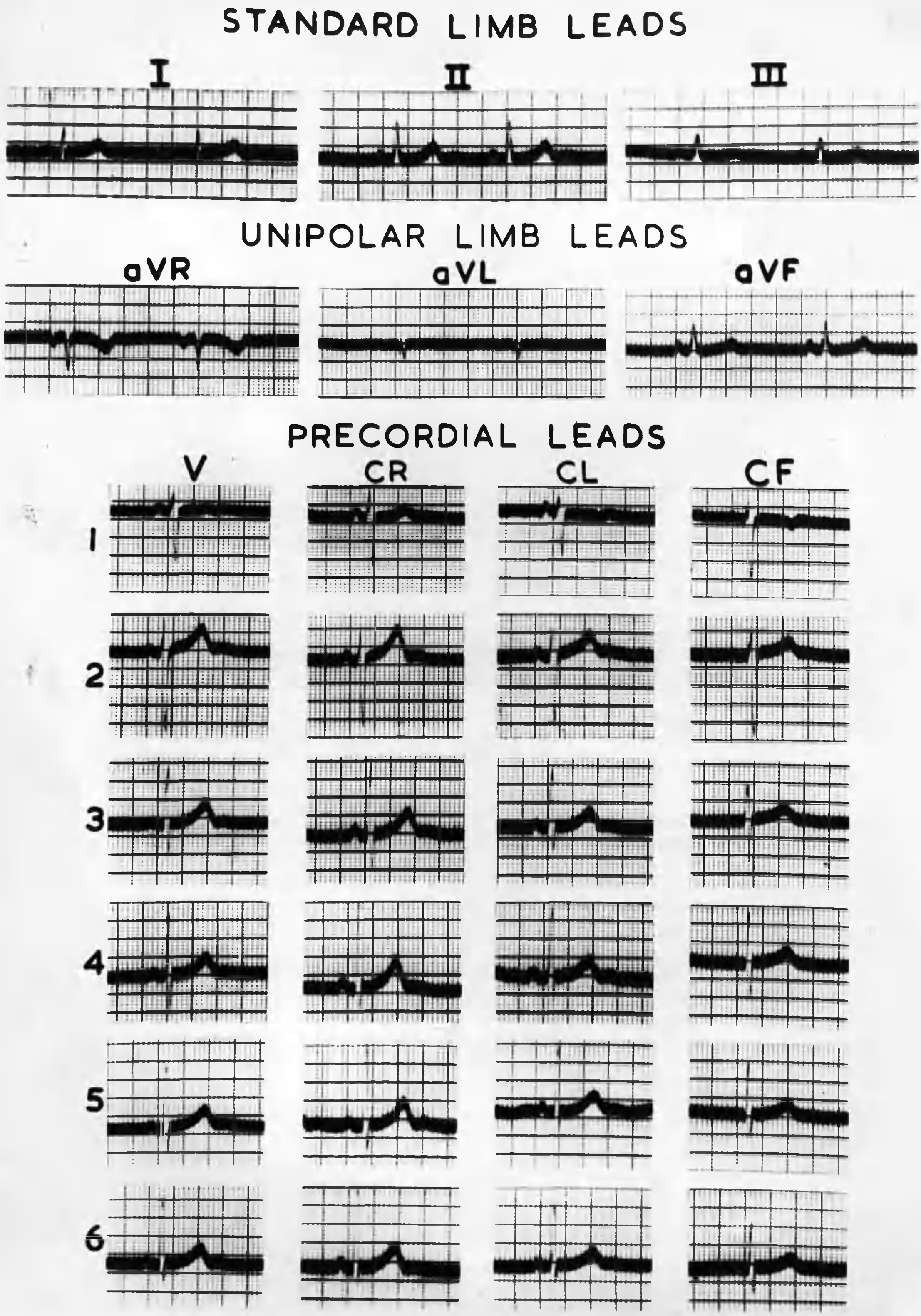
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most marked in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. IO — PLATE 38

NORMAL.

A.McL.

age I7 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

Lead aVR has inverted P and T waves and a QS pattern. There is a small inverted U wave.

Lead aVL has practically flat P and T waves and a small vibratory qrs pattern. There is no U wave.

Lead aVF has upright P and T waves and an R pattern. There is a small upright U wave.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

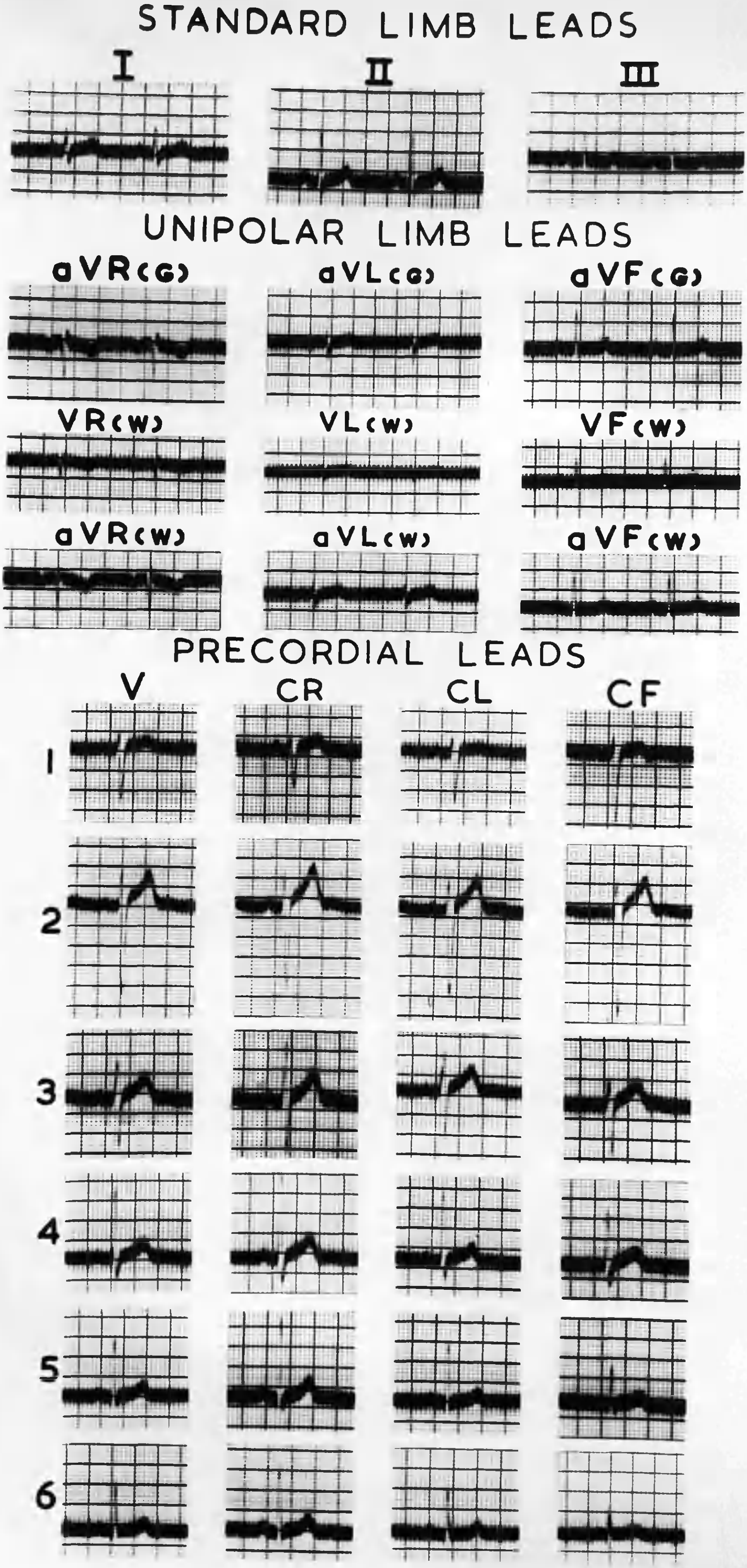
P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

U wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.II PLATE 39.

NORMAL. A.C.

Age 25 years

STANDARD LIMB LEADS.

These show slight tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have practically flat P and low upright T waves and an rs pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-vertical.

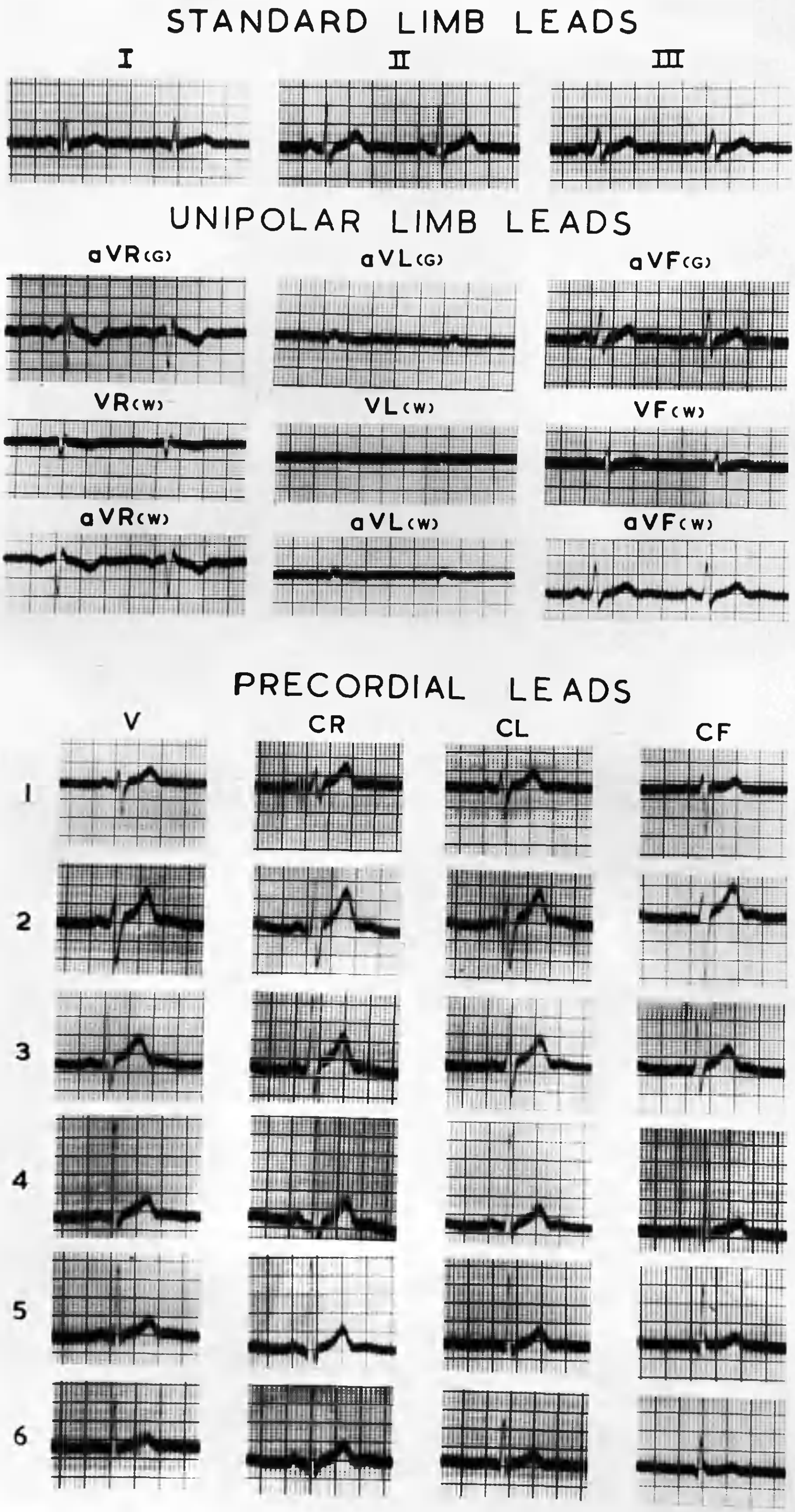
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. I2 PLATE 40

NORMAL.

F.O'R.

Age 30 years.

STANDARD LIMB LEADS.

These show S waves in leads II and III but there is no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and T waves and a small vibratory qr pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-vertical.

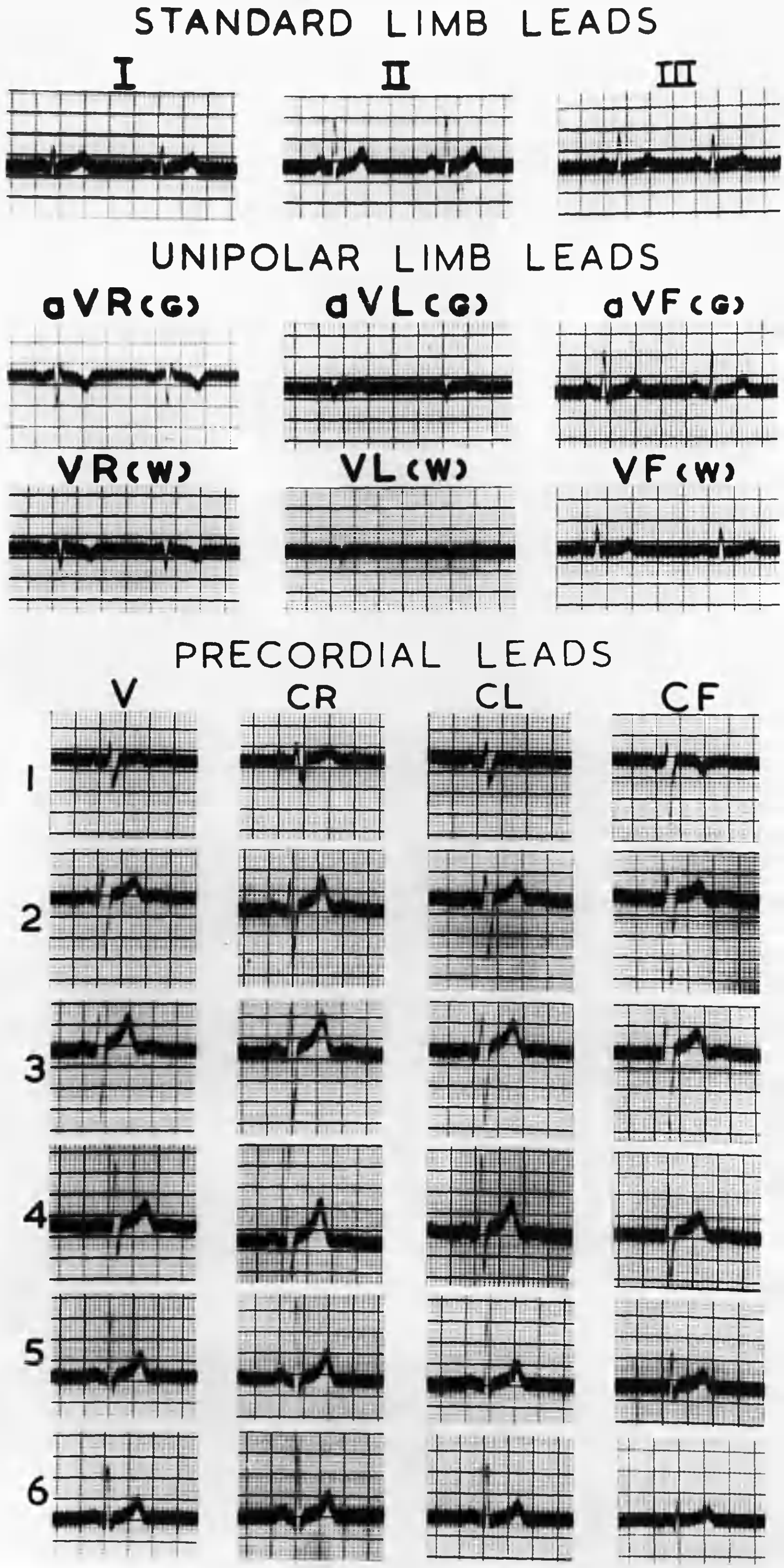
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. An exception is the S wave in the leads over the left precordium, which is present in CR and absent in CF due to the r' in VR and the s in VF respectively.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. I3 PLATE 4I

NORMAL. W.McG.

Age 34 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and shallow upright T waves and an rs pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-vertical.

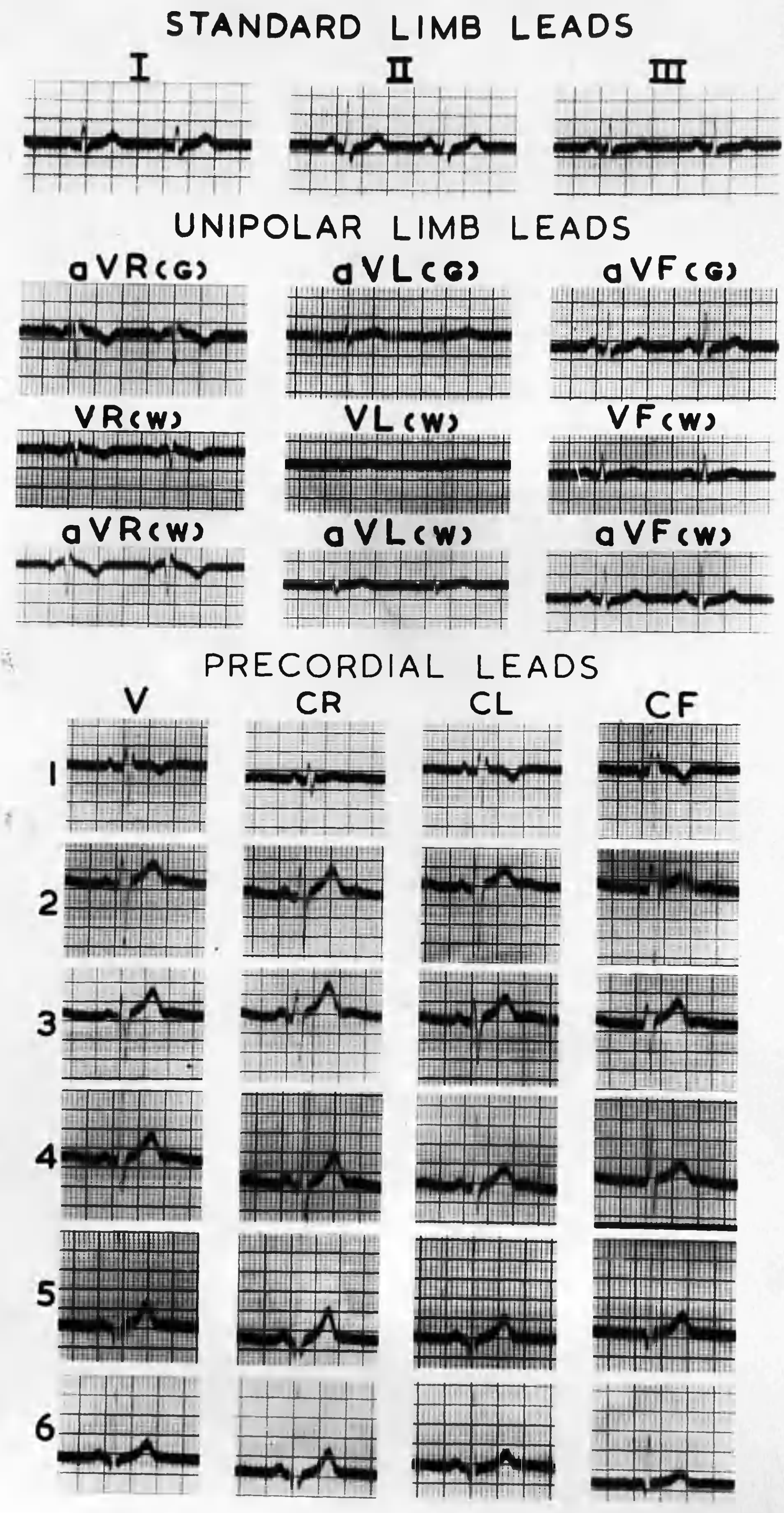
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S wave in leads over the left precordium is most prominent in CR and least prominent in CF due to the r' in VR and the s in VF respectively.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 2, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 14 PLATE 42.

NORMAL. I.S.

Age 35 years.

STANDARD LIMB LEADS.

These show slight tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have inverted P and upright T waves and a qrs pattern.

The VF leads have upright P and T waves and a qRs pattern.

Electrically the heart is semi-vertical.

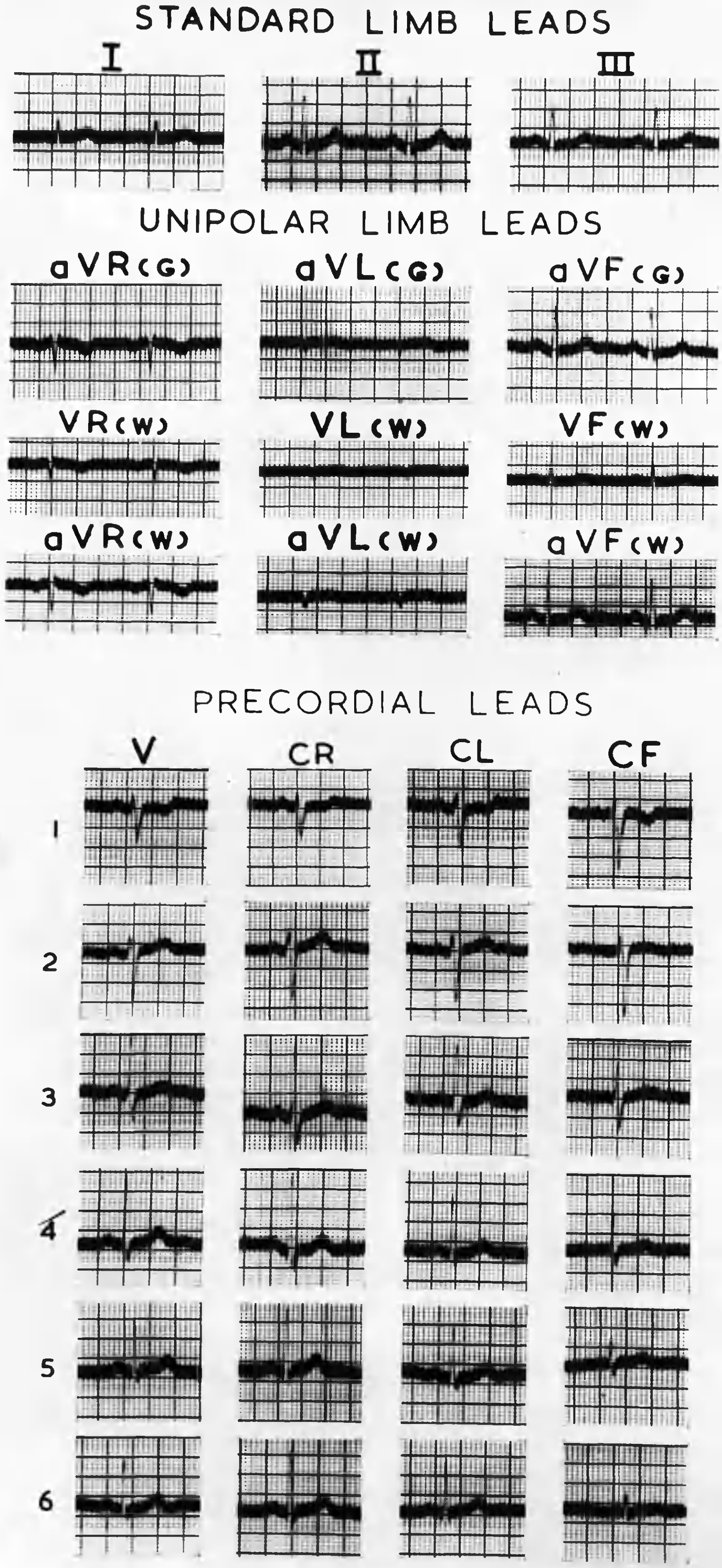
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The r' in position I is smallest in CR due to the r' in VR.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. I5 PLATE 43

NORMAL. Mrs. C.H.

Age 38 years.

STANDARD LIMB LEADS.

These show a tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and T waves and a qs pattern.

The VF leads have upright P and T waves and a qRs pattern. The P-R and S-T segments are slightly depressed.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

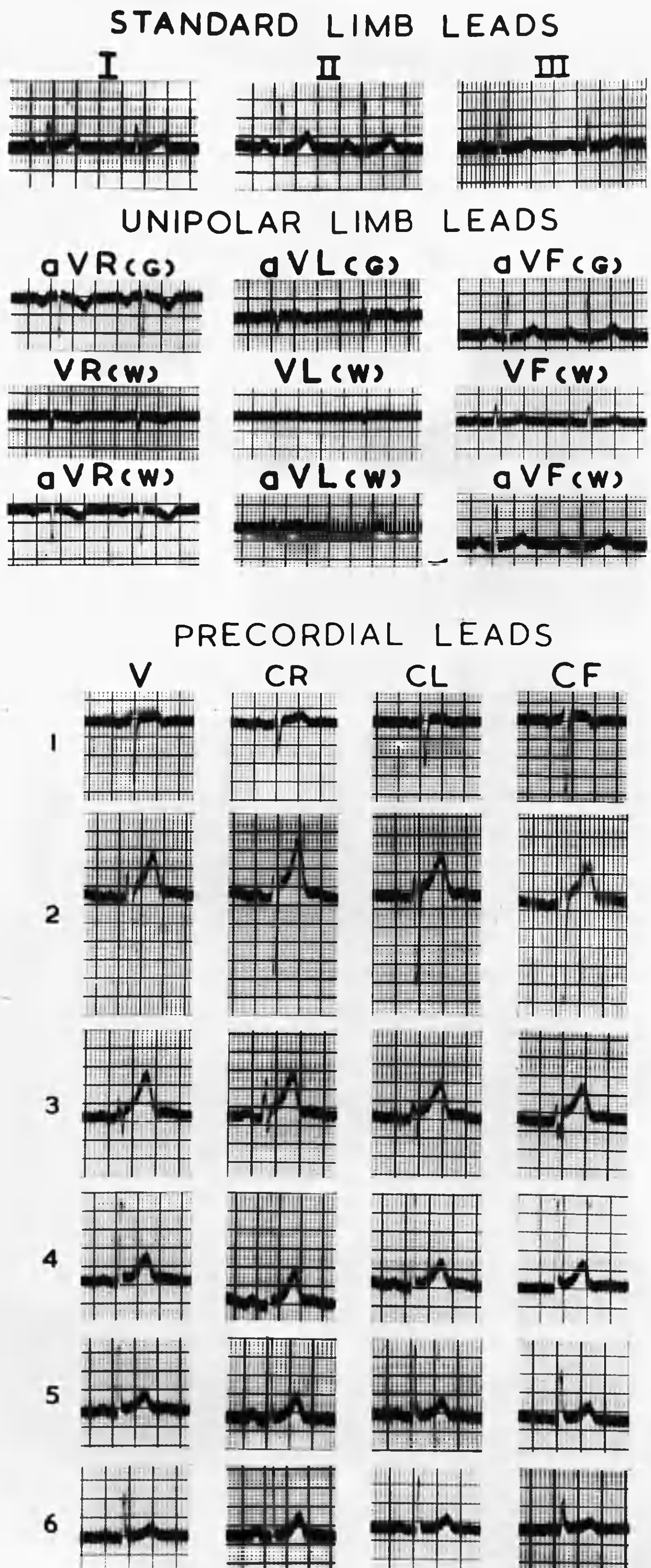
P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.

The effect of the P-R and S-T depression in VF is seen in position I where these segments are depressed in CR, CL and V but not in CF.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

NORMAL.

D.W.

Age 42 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P waves, low upright T waves and an rS pattern.

The VF leads have upright P and T waves and a qRs pattern.

Electrically the heart is semi-vertical.

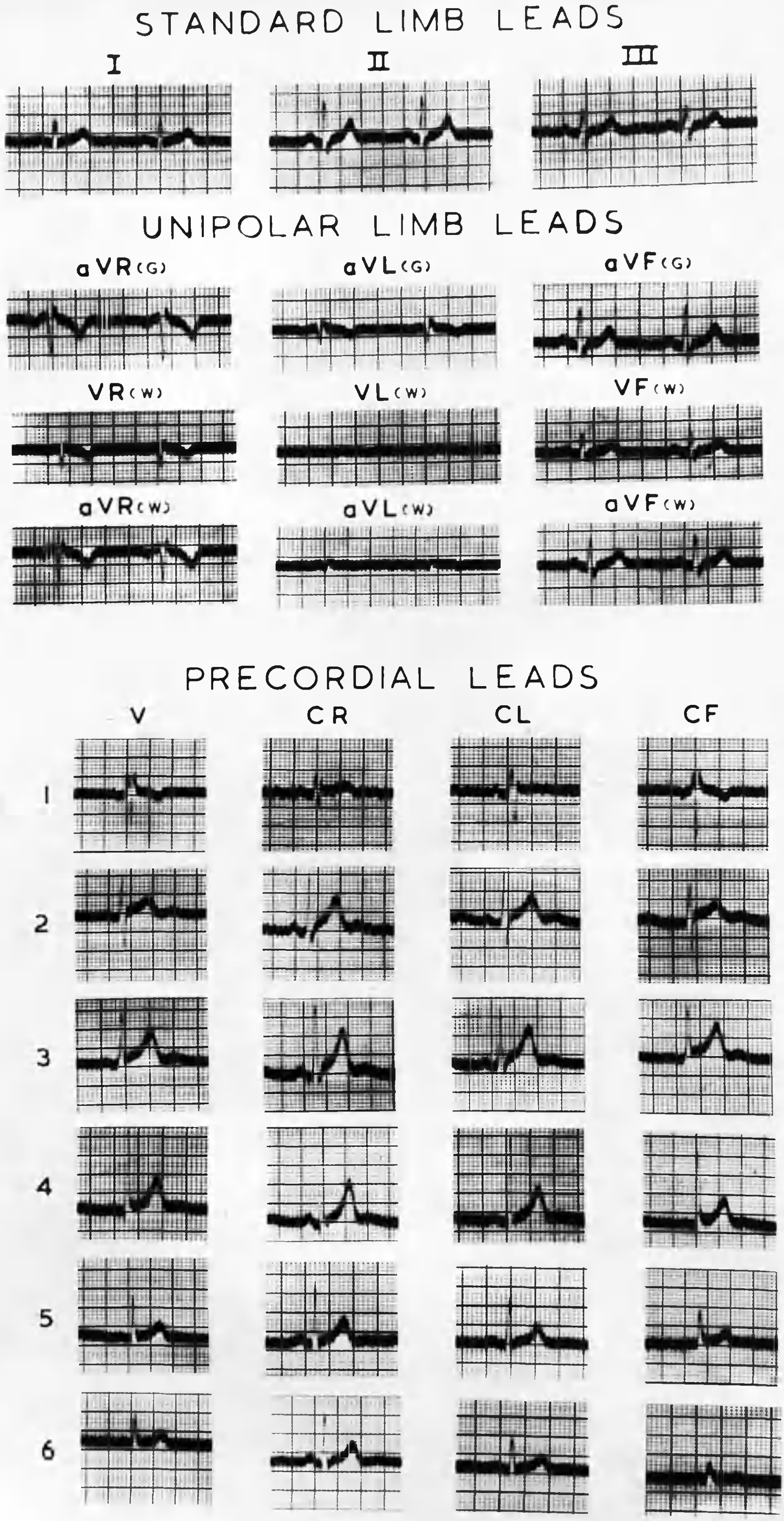
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.
There is notching of the RS in all leads in position 3. In CR it occurs on the upstroke of the R wave; in CL it is at the peak of the R wave, and in CF it is at the tip of the S wave. In the V lead it occurs on the descending limb of the R wave, i.e. intermediate between the other three.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the V leads.

The differences apart from the splintering of the QRS complex are most obvious in positions I,5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. I7 PLATE 45

NORMAL.

R.S.

Age 50 years.

STANDARD LIMB LEADS.

These show S waves in leads II and III but there is no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and T waves and a qr pattern.

The VF leads have upright P and T waves and a qRs pattern.

Electrically the heart is semi-vertical.

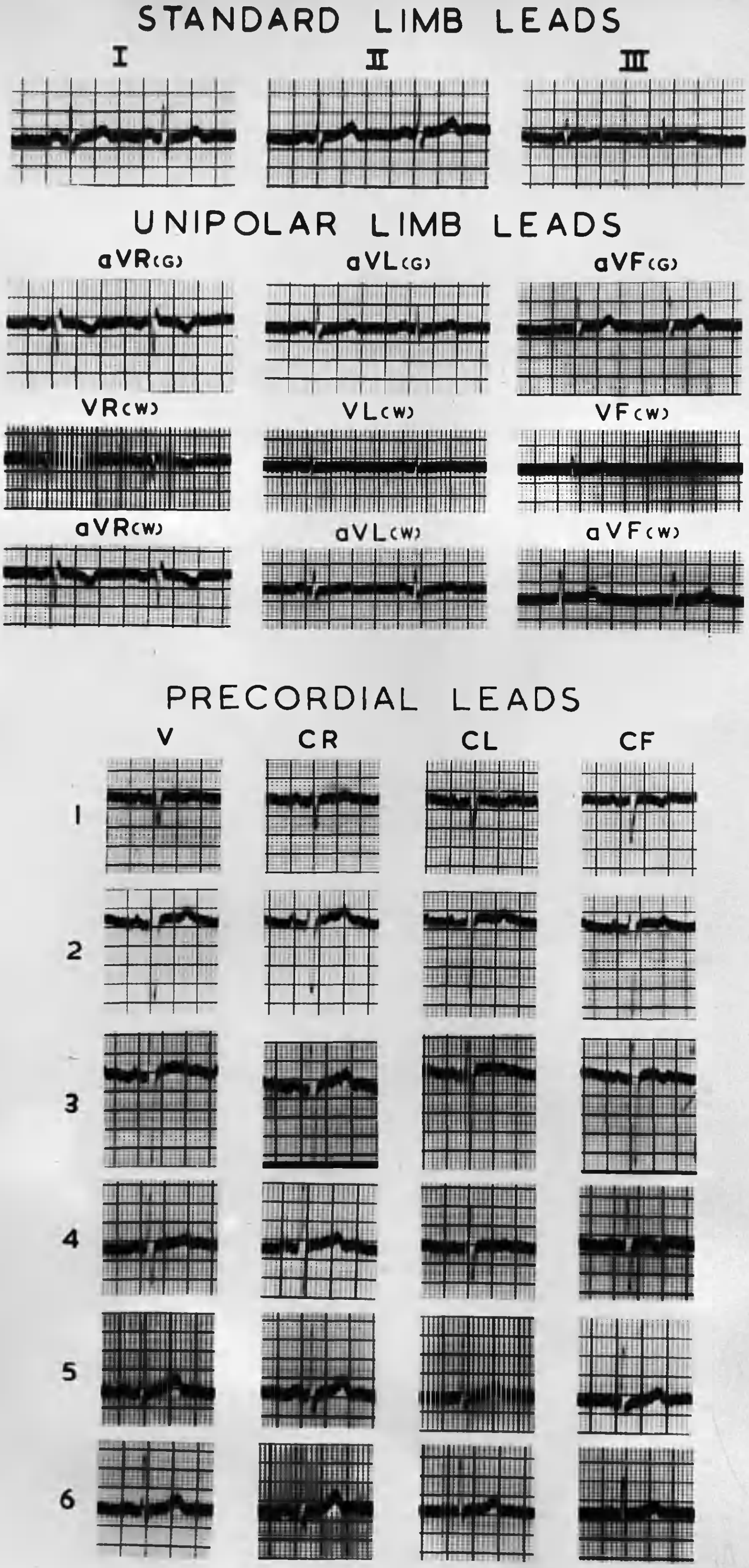
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. An exception is the S wave in the leads over the left precordium, which is present in CR and absent in CF, due to the r' in VR and the s in VF respectively.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I,2,5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 18 PLATE 46

NORMAL.

J.McG.

Age 15 years.

STANDARD LIMB LEADS.

These show bifid P waves and small S waves in all leads. There is no axis deviation. There are fairly prominent U waves in all leads.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern. There is an inverted U wave.

The VL leads have upright bifid P and low upright T waves and an Rs pattern. There is a small upright U wave.

The VF leads have flat P and upright T waves and an Rs pattern. There is an upright U wave.

Electrically the heart is in the intermediate position.

PRECORDIAL LEADS.

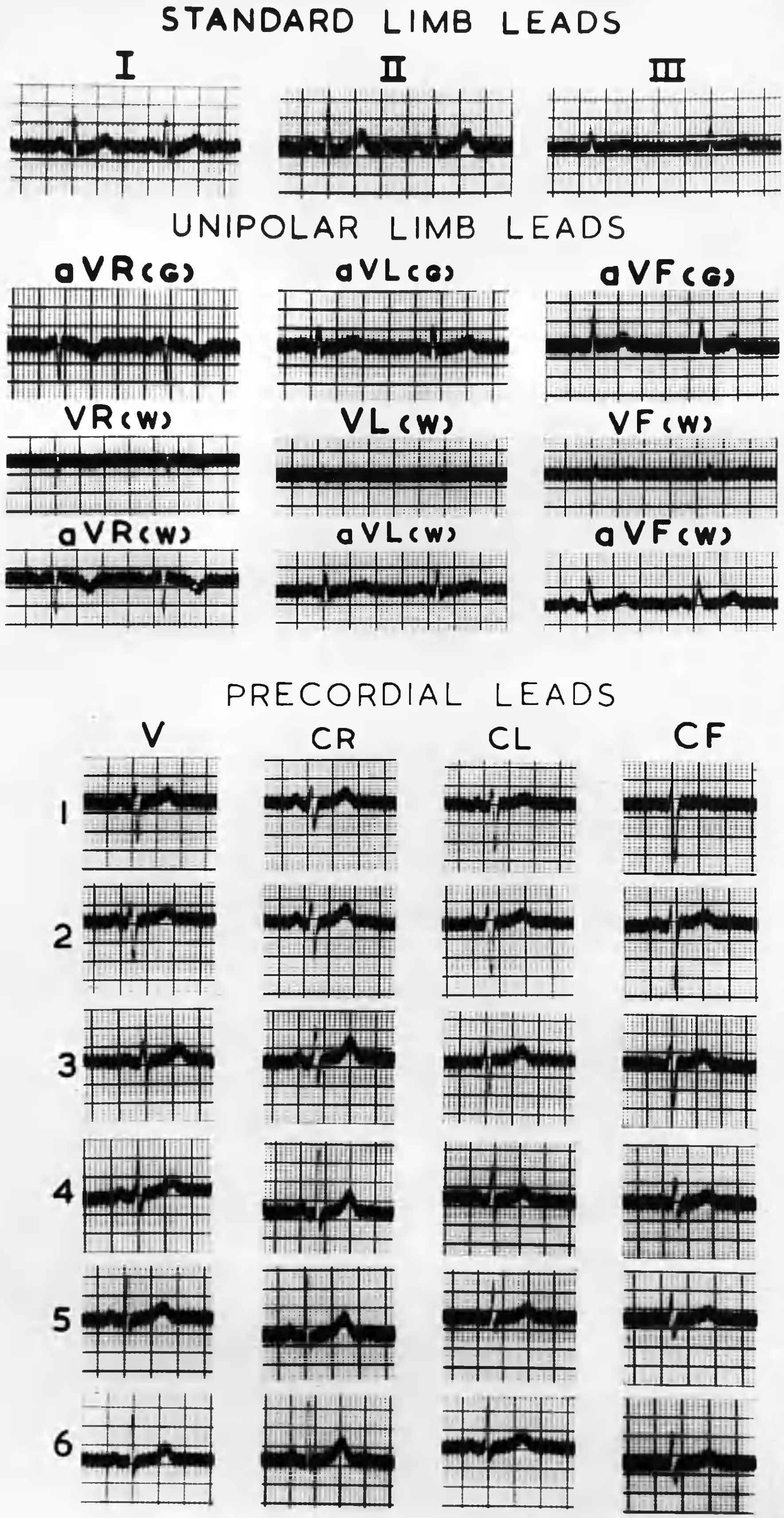
P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S in leads over the left precordium is most prominent in CR due to the late r in VR.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

U wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are obvious in all positions.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.I9 PLATE 47

NORMAL.

Mrs. E.D.

Age 2I years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have upright P and T waves and a qRs pattern.

The VF leads have upright P and T waves and an R pattern.

Electrically the heart is in the intermediate position.

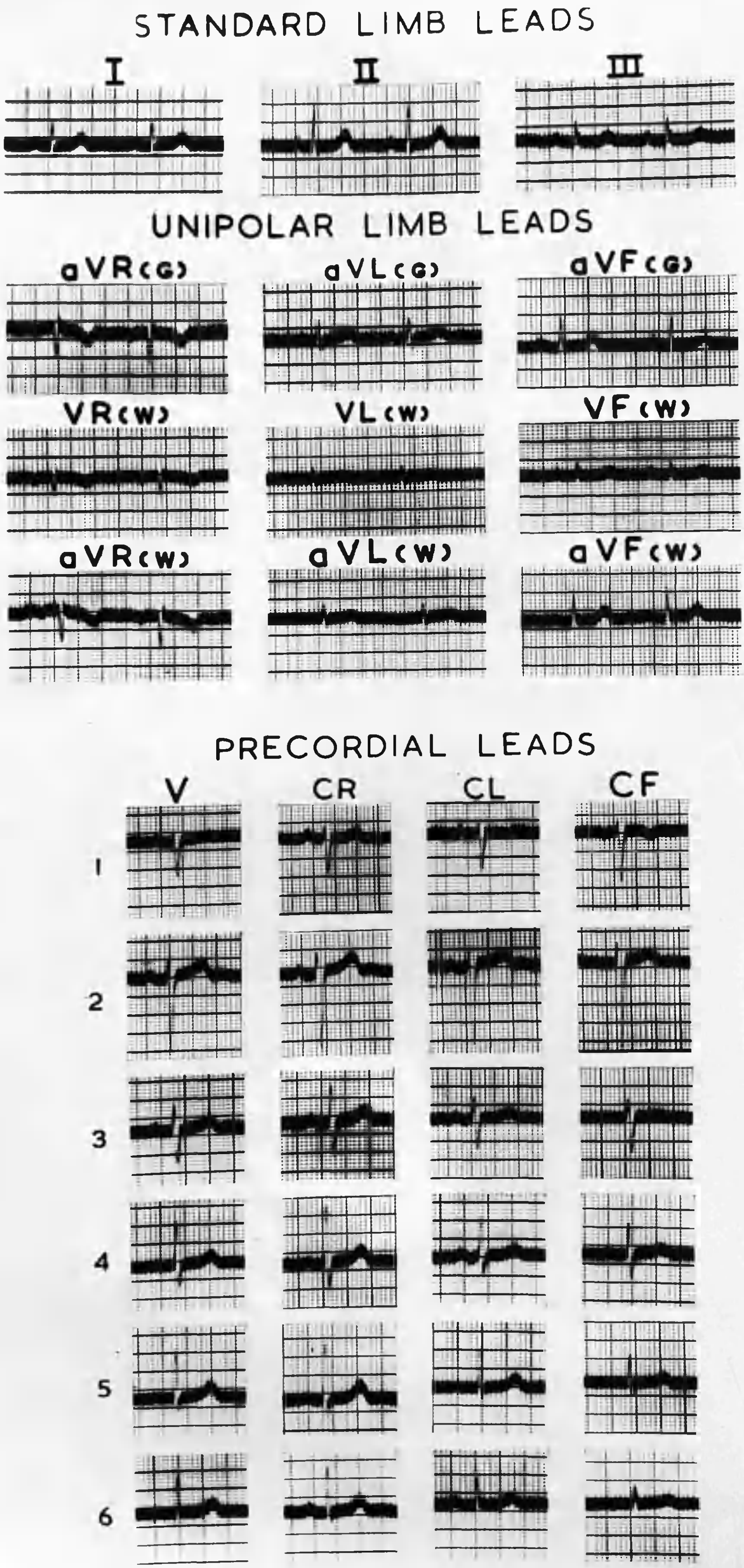
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads,least positive in the CL and CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

T wave: this is most positive in the CR leads,least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I,2 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 20 PLATE 48

NORMAL.

Mrs. M.B.

Age 22 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have practically flat P and low upright T waves and an Rs pattern.

The VF leads have upright P and T waves and a qR pattern.

Electrically the heart is in the intermediate position.

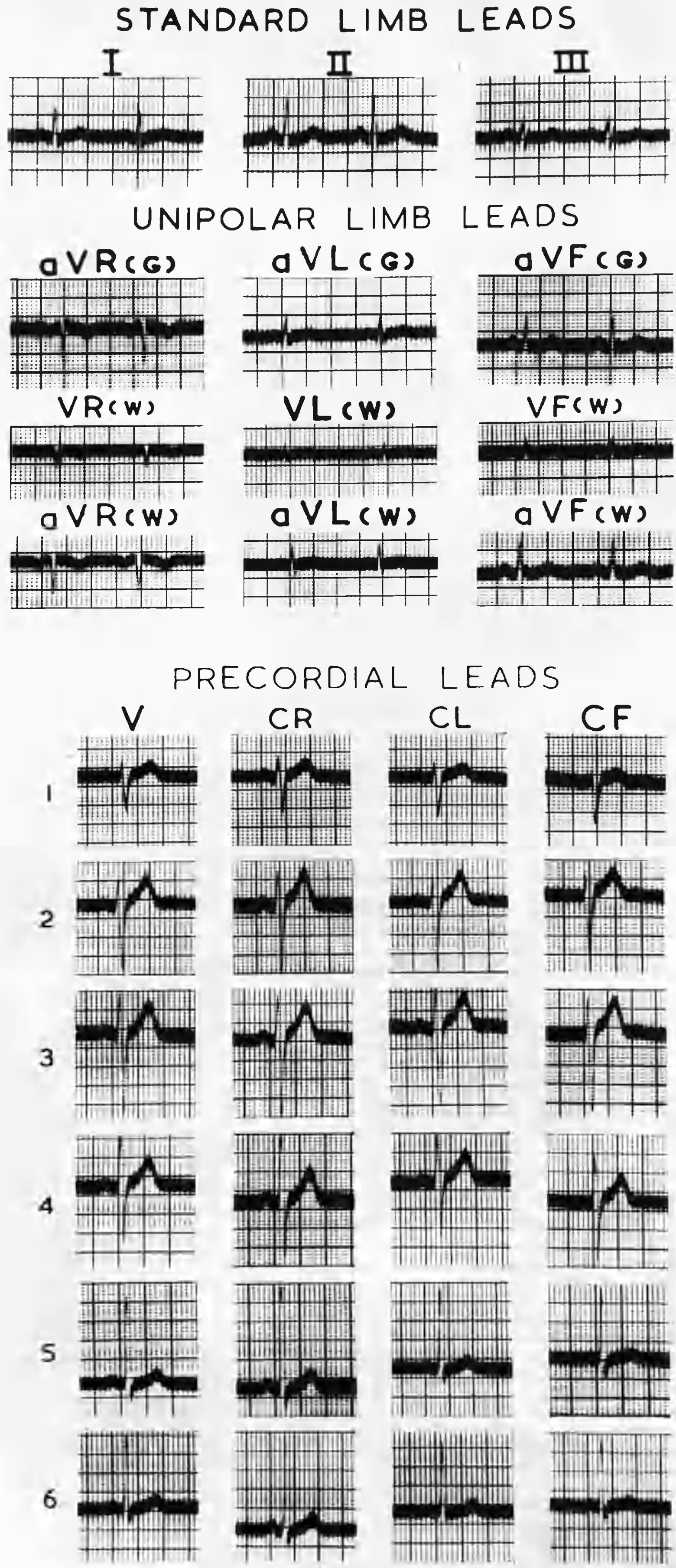
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S in leads over the left precordium is most prominent in CR due to the r' in VR.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.21 PLATE 49

NORMAL.

A.M.

Age 54 years.

STANDARD LIMB LEADS.

Lead III has an RSr' pattern and there is no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have practically flat P and T waves and a qRs pattern.

The VF leads have upright P and T waves and an R pattern.

Electrically the heart is in the intermediate position.

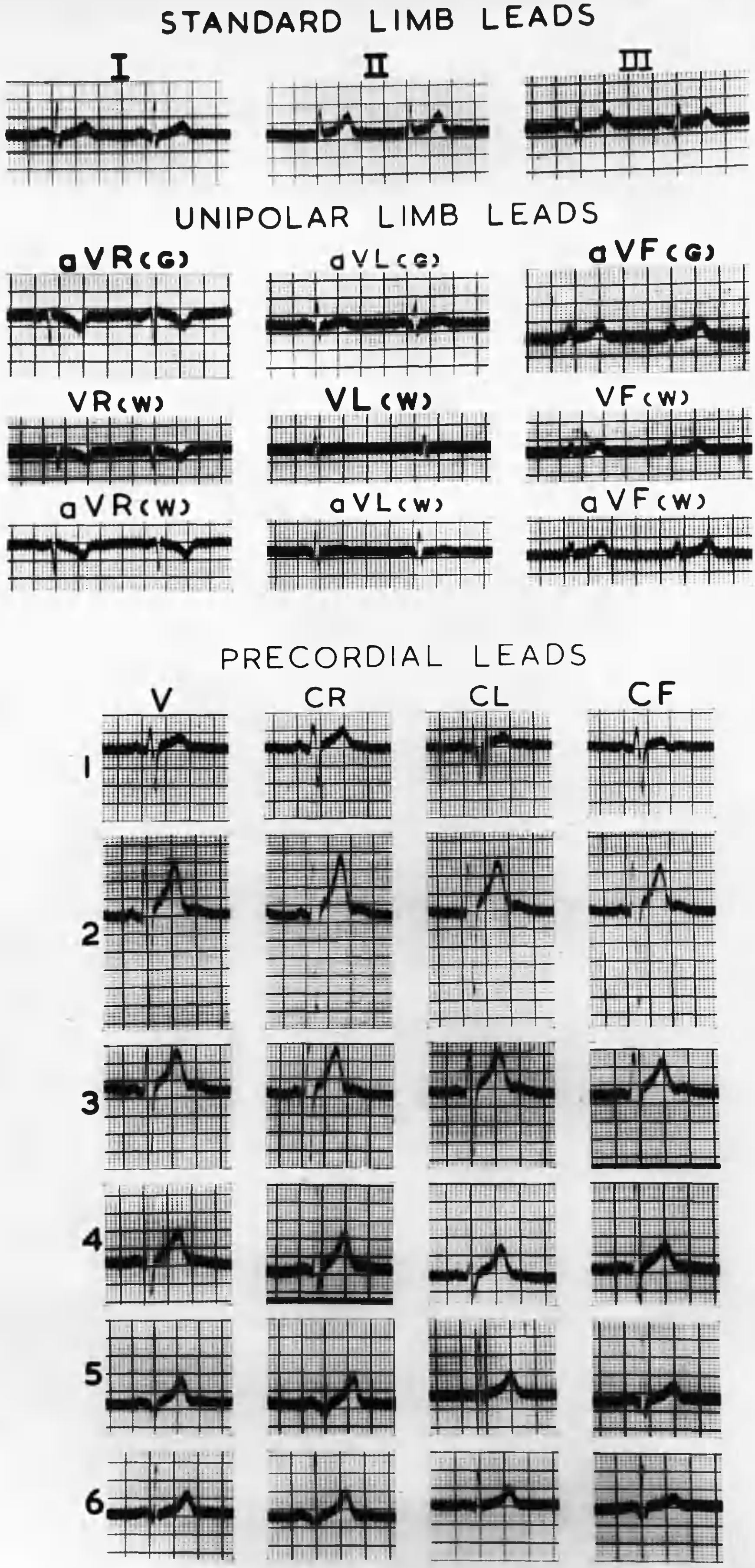
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the V leads. The CL leads are practically identical with the CF leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences in this case are not very striking and are most apparent in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 22 PLATE 50

NORMAL. A.B.

Age I9 years.

STANDARD LIMB LEADS.

R is splintered slightly at its base in lead II; there is an rSR' pattern in lead III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves, and an rSr' pattern.

The VL leads have practically flat P and T waves and a qRs pattern.

The VF leads have a flat P and upright T waves, and a splintered rs pattern.

Electrically the heart is semi-horizontal.

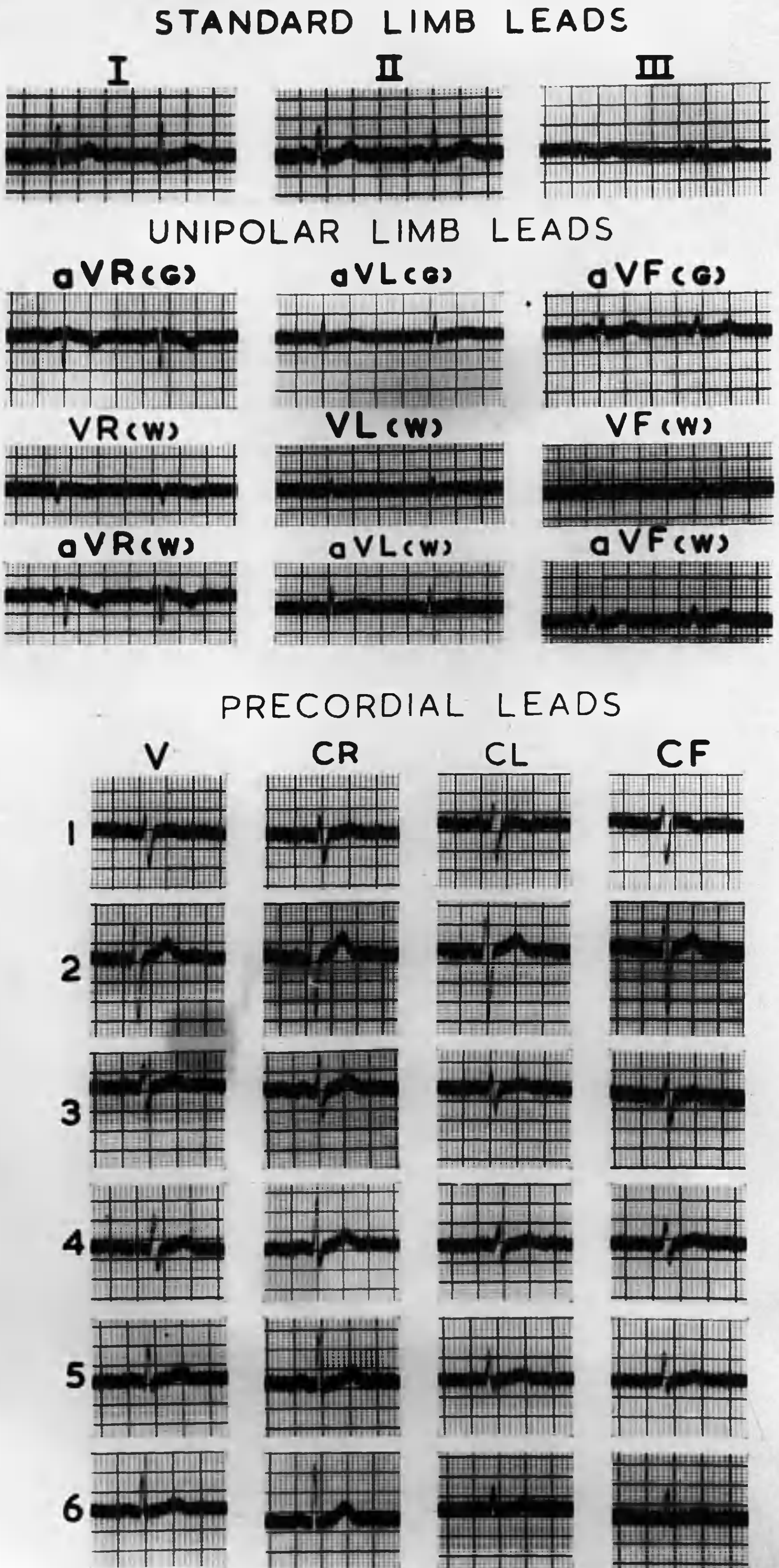
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CR leads, intermediate in the CF and V leads and least positive in the CL leads, apart from the S wave which is smallest in the CL leads because of the fairly prominent terminal S in VL.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 2, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 23 PLATE 5I

NORMAL. Miss C.D.

Age 24 years.

STANDARD LIMB LEADS.

Lead III has a small rsr' pattern. There is a tendency to L.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have flat P and practically flat T waves and a qRs pattern.

The VF leads have upright P and T waves and an r pattern.

Electrically the heart is semi-horizontal.

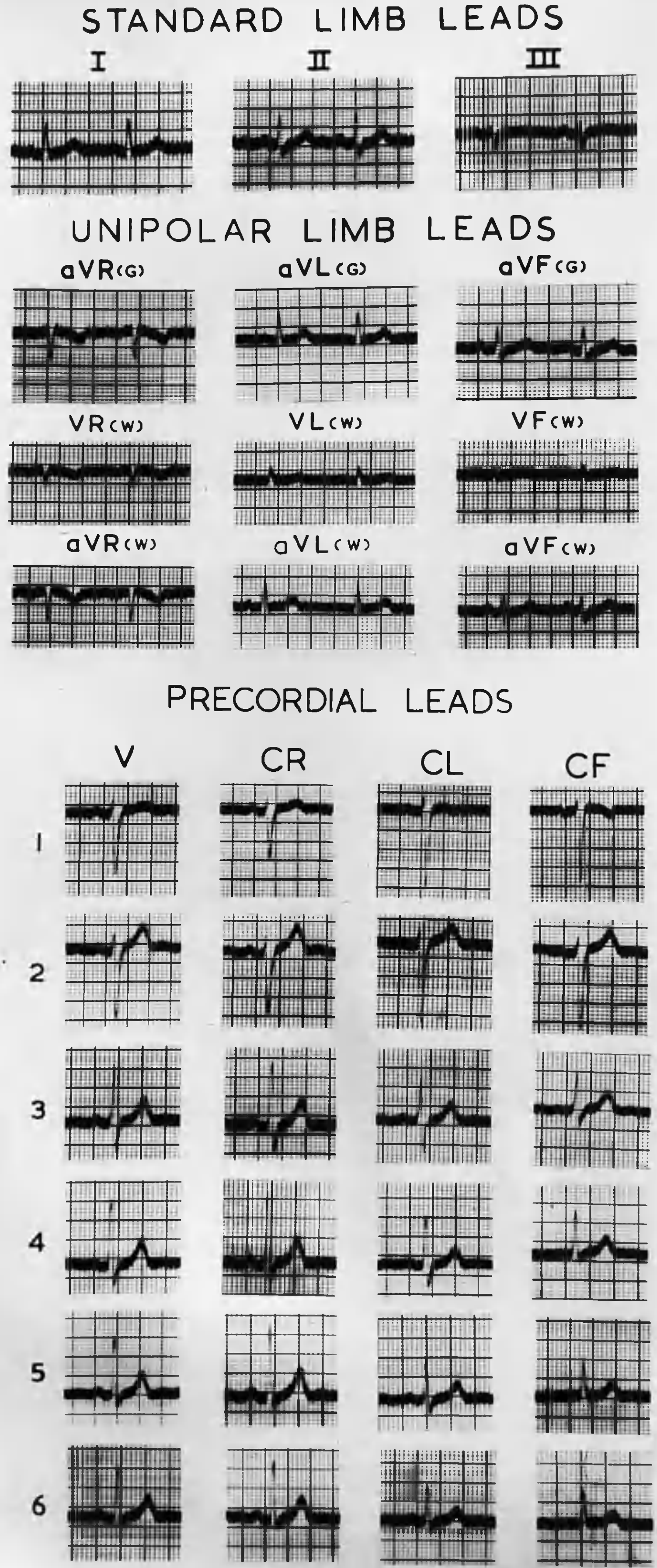
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 24 PLATE 52

NORMAL. Mrs.A.G.

Age 36 years.

STANDARD LIMB LEADS.

These show a tendency to L.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have flat P and upright T waves and a qR pattern.

The VF leads have upright P and T waves and an RS pattern.

Electrically the heart is semi-horizontal.

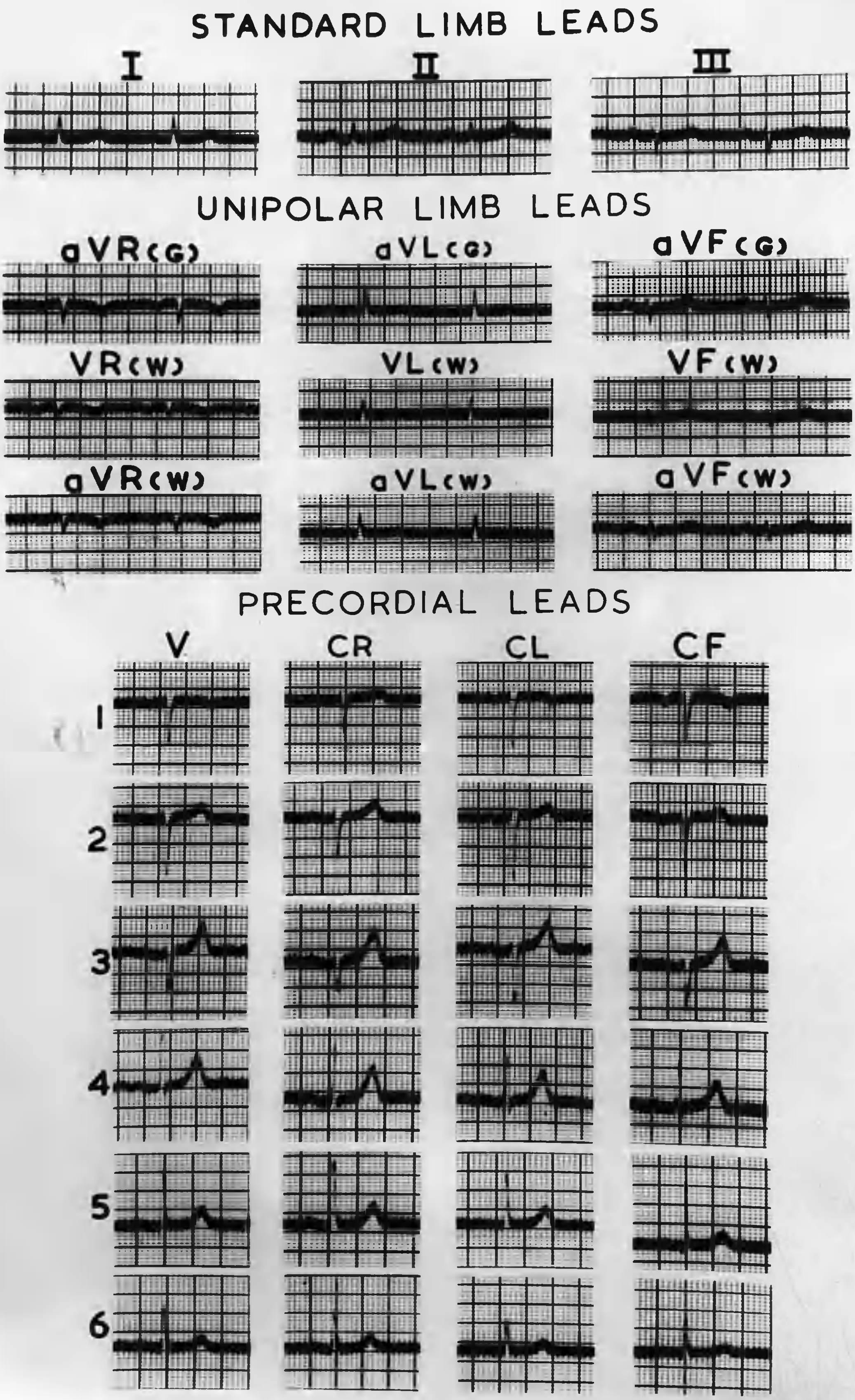
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads. The S in leads over the left precordium is least prominent in CF due tp the S in VF.

T wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

The differences are most obvious in positions I,5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.25 PLATE 53

NORMAL. J.M.

Age 62 years.

STANDARD LIMB LEADS.
These show L.A.D.

UNIPOLAR LIMB LEADS.
The VR leads have inverted P and T waves and a QS pattern.

The VL leads have practically flat P and T waves and a qR pattern.

The VF leads have upright P and T waves and an rs pattern.

Electrically the heart is semi-horizontal.

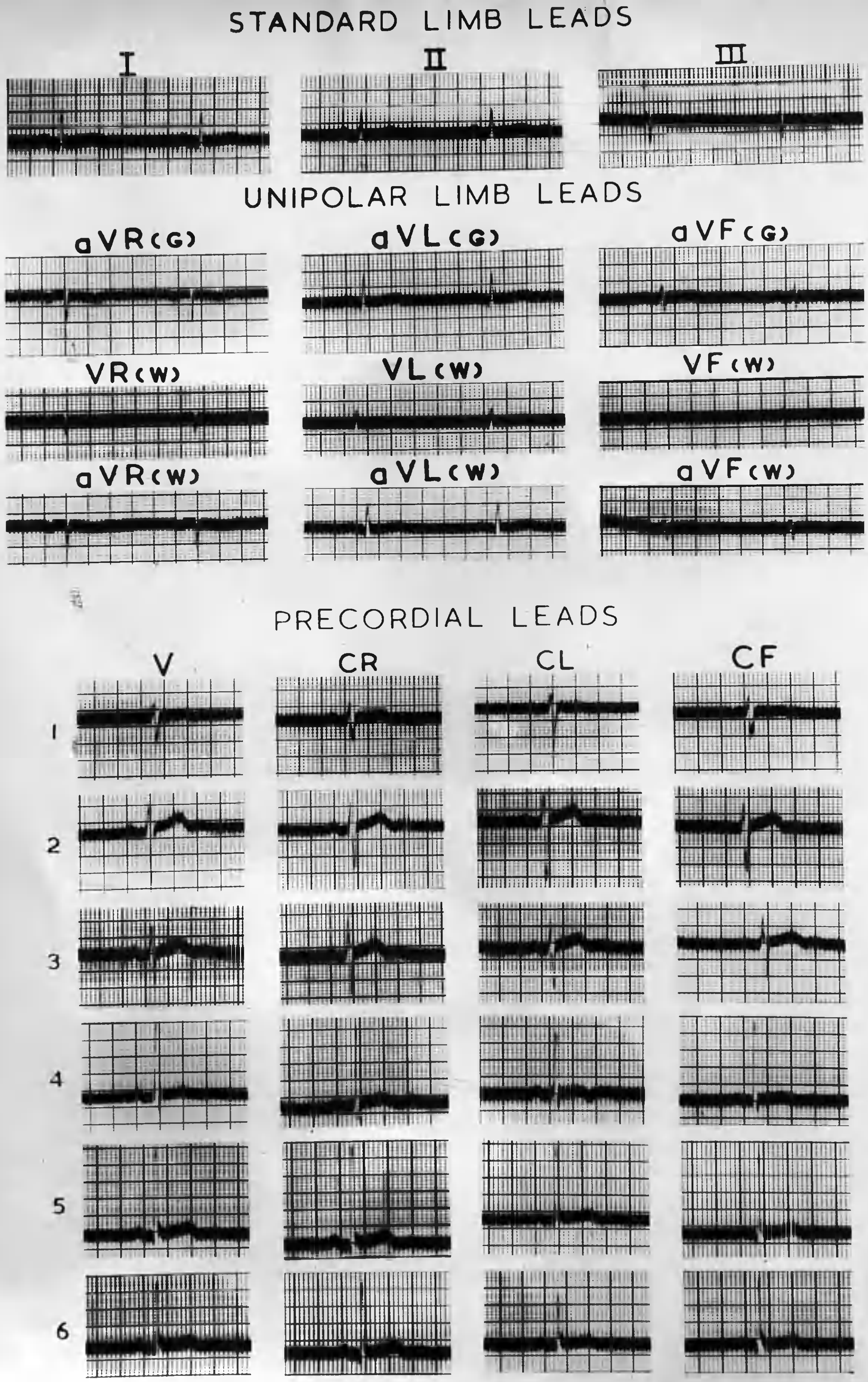
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I,2 and 6.



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.26 PLATE 54

NORMAL. S.N.

Age 47 years.

STANDARD LIMB LEADS.

These show L.A.D. with shallow inverted T wave in lead III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a QS pattern.

The VL leads have practically flat P and upright T waves and a qR pattern.

The VF leads have upright P and practically flat T waves and an rs pattern.

Electrically the heart is horizontal.

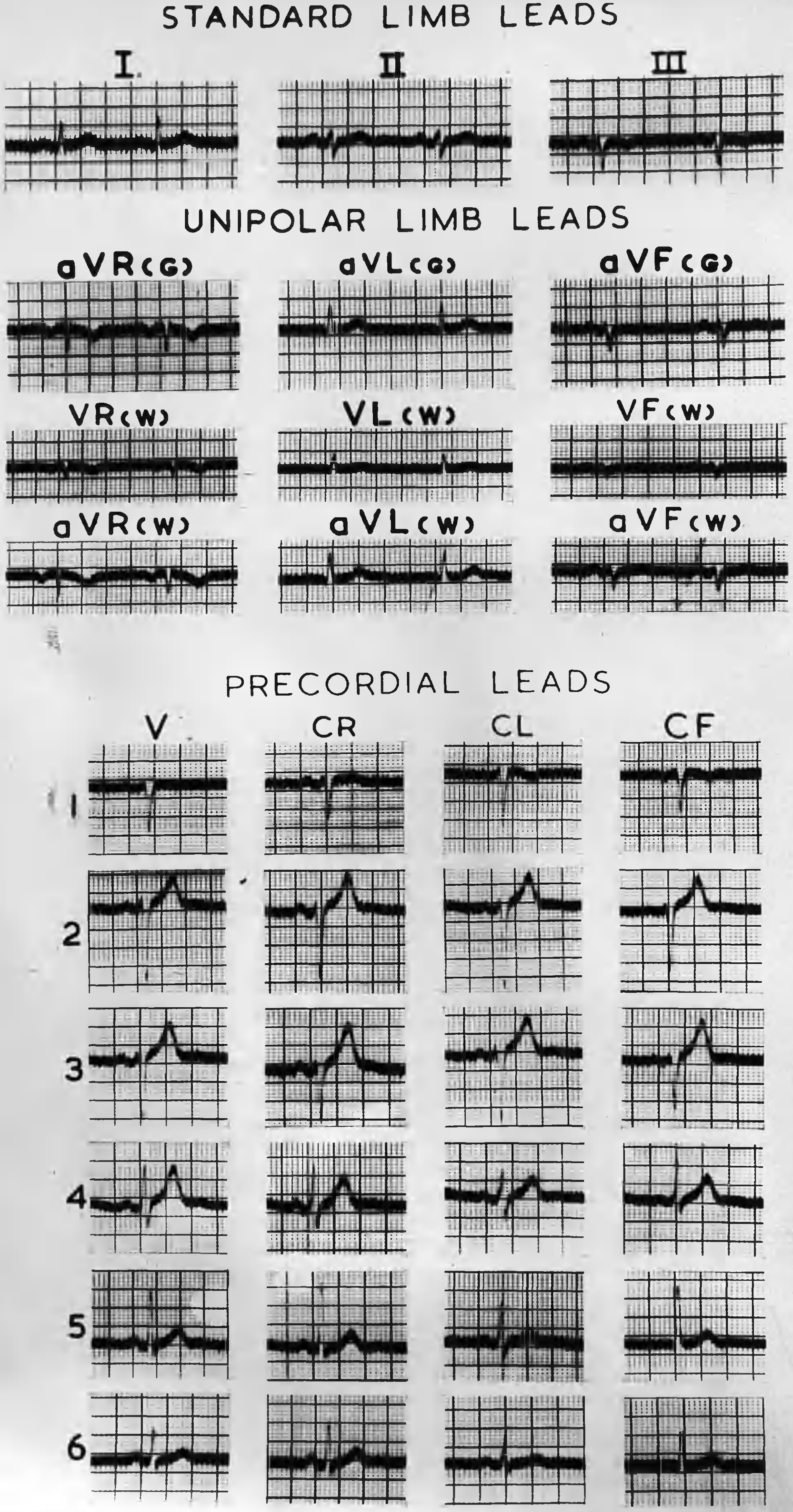
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads. The Q wave in leads over the left precordium is least obvious in CL due to the q in VL.

T wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads. Because of the low amplitude of the T waves in all the unipolar limb leads, the differences in the precordial leads are slight.

The differences are most obvious in positions I,5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.27 PLATE 55

NORMAL.

J.M.

Age 49 years.

STANDARD LIMB LEADS.

These show L.A.D. with slight inversion of T in lead III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have a flat P and upright T waves and a qR pattern.

The VF leads have an upright P and practically flat T waves and an rS pattern.

Electrically the heart is horizontal.

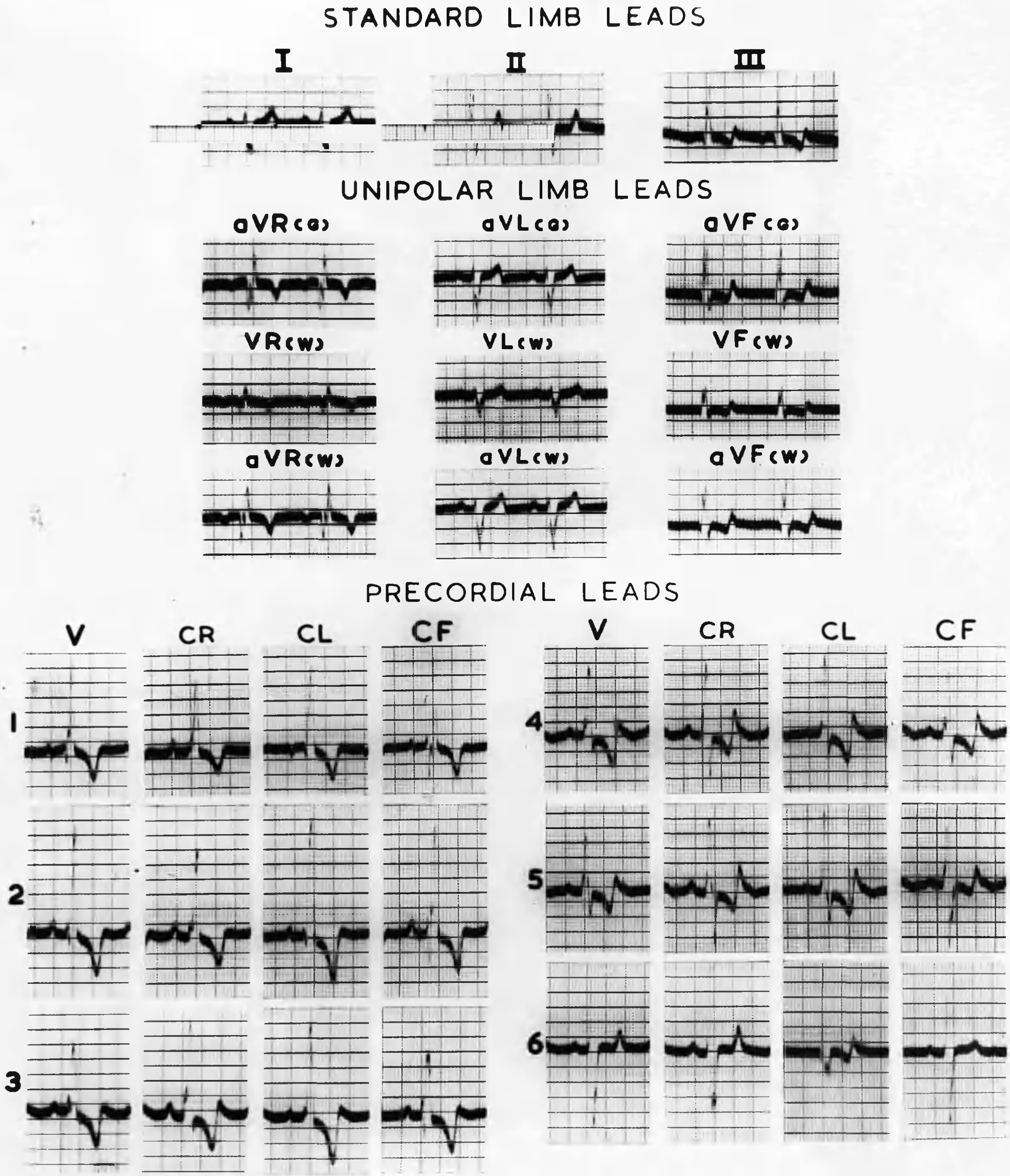
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

These differences are most obvious in positions I, 4, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(a)
aVL(a)
aVF(a)
VR(w)
VL(w)
VF(w)
aVR(w)
aVL(w)
aVF(w)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
V
CR
CL
CF
4
5
6

ABNORMAL. M.H.

Diagnosis: Congenital Heart Disease: Interauricular and Interventricular Septal Defect.

Age I4 years

STANDARD LIMB LEADS.

These show the appearances of right bundle branch block.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a notched QR pattern.

The VL leads have upright P and T waves and an rS pattern.

The VF leads have flat P and diphasic T waves and a notched qRs pattern.

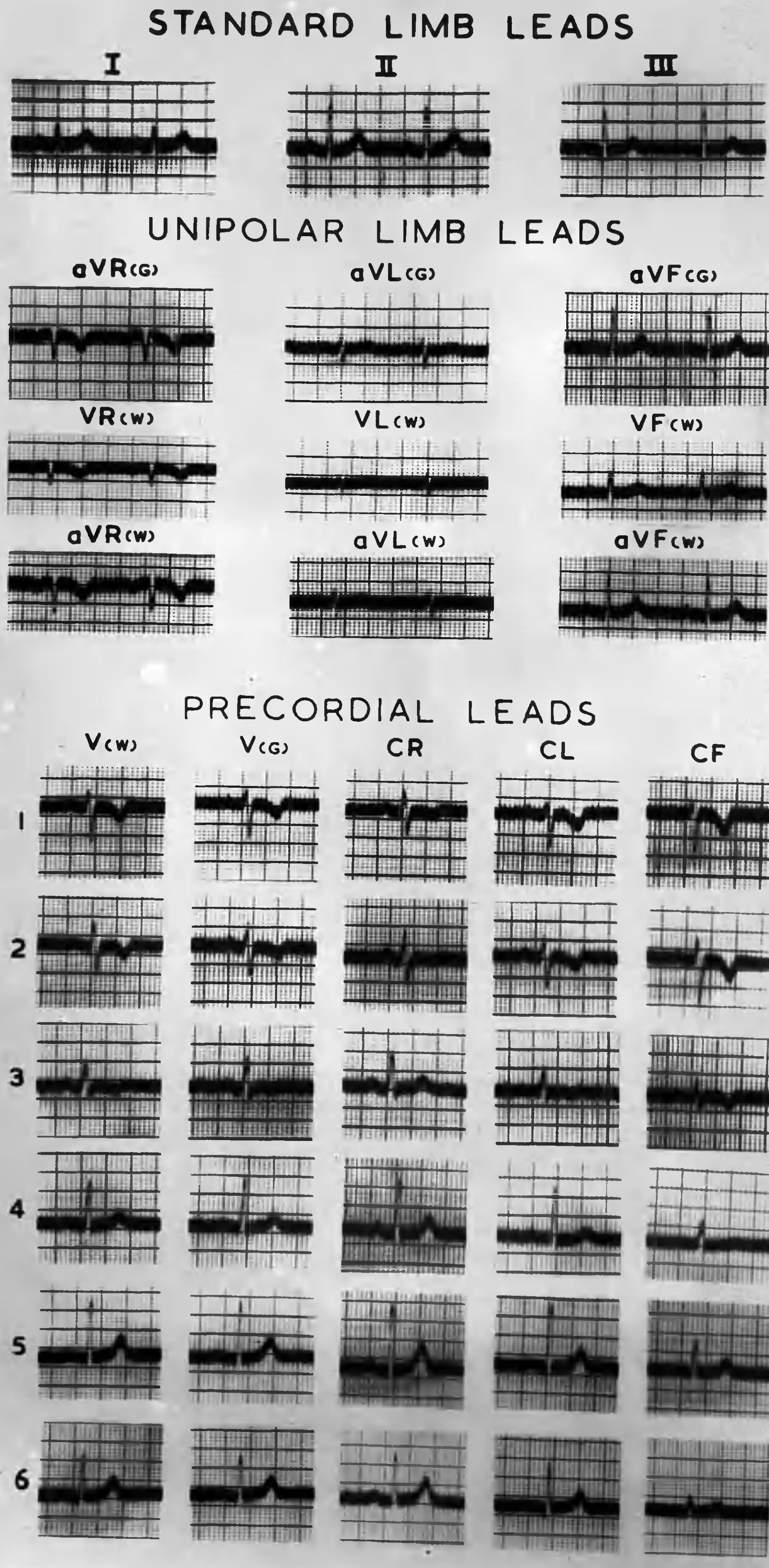
Electrically the heart is vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CL leads, least positive in the CF and CR leads and intermediate in the V leads. The complexity of the initial ventricular deflections over the right precordium makes comparison difficult but it can be seen that the V leads have a pattern intermediate between the extremes of the CR, CL and CF leads.

T wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads. This is best seen in position 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V(W)
V(G)
CR
CL
CF
1
2
3
4
5
6

CASE NO. 29 PLATE 57

ABNORMAL. Mrs.C.P.

Diagnosis: Pulmonary Tuberculosis. Age 29 years.

STANDARD LIMB LEADS.
These show a tendency to R.A.D.

UNIPOLAR LIMB LEADS.
The VR leads have inverted P and T waves and a QS pattern.

The VL leads have practically flat P and T waves and an rS pattern.

The VF leads have upright P and T waves and a qRs pattern.

Electrically the heart is vertical.

PRECORDIAL LEADS.

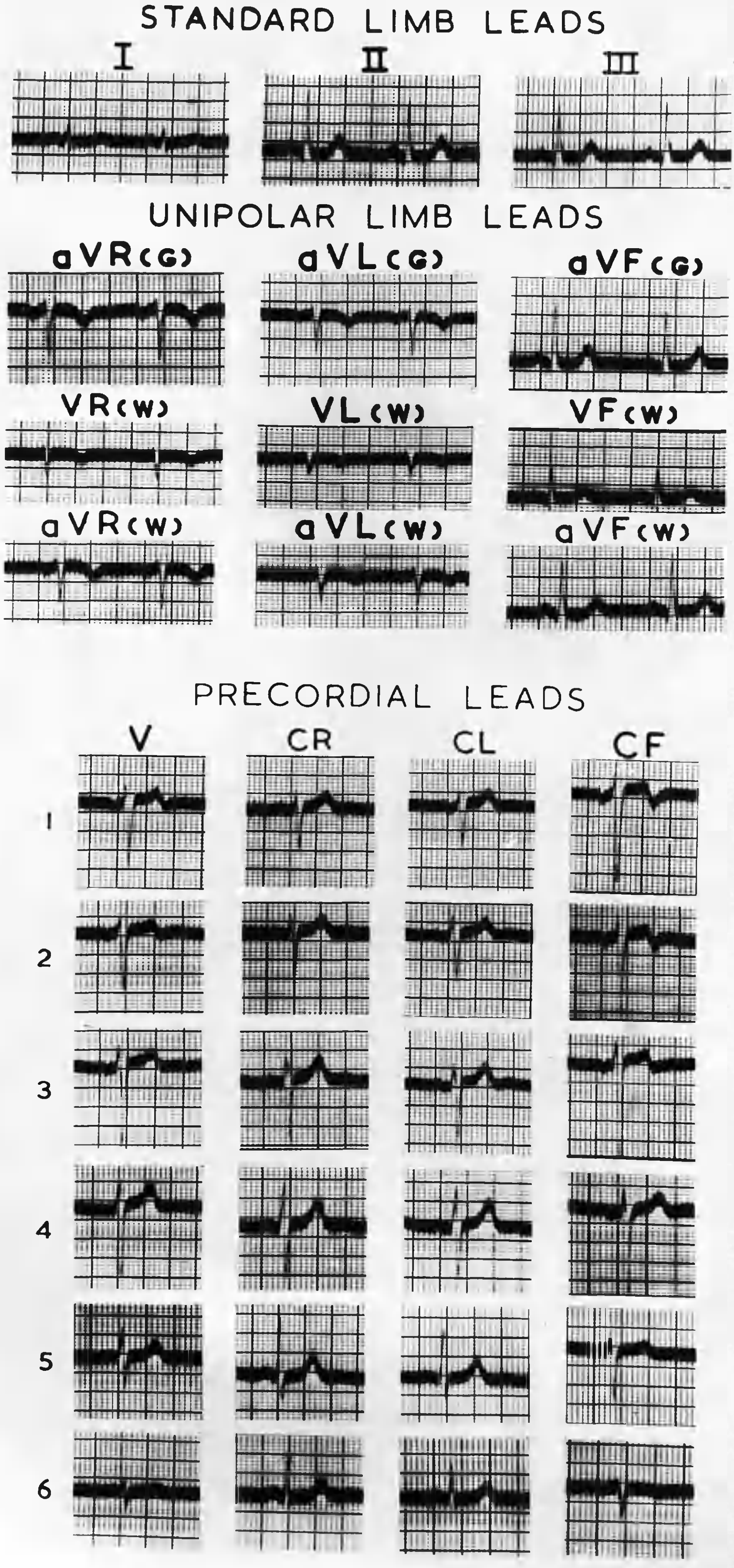
P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 2, 3 and 6.

There are slight differences between the V(W) and V(G) leads particularly in position 3.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

ABNORMAL. J.F.

Diagnosis: Chronic Bronchitis and Emphysema. Age 49 years.

STANDARD LIMB LEADS.

These show a tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rS pattern.

The VL leads have slight inversion of P and T waves and an rS pattern.

The VF leads have upright P and T waves and a qR pattern.

Electrically the heart is vertical.

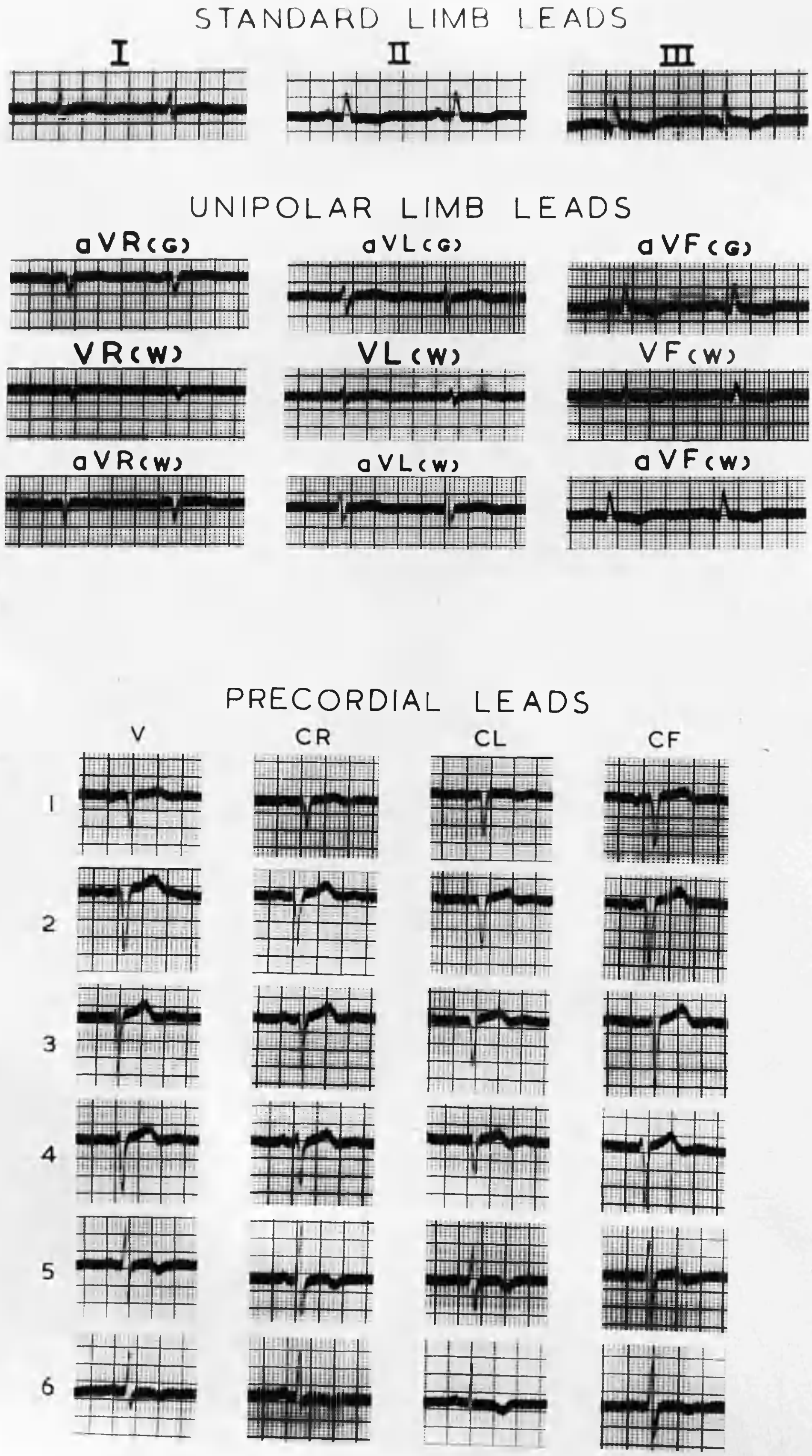
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are obvious in all positions.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 31 PLATE 59

ABNORMAL. Mrs.M.M.

Diagnosis: Essential Hypertension. Age 52 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and low upright T waves and a QS pattern.

The VL leads have practically flat P and upright T waves and an RS pattern.

The VF leads have upright P and inverted T waves and a qR pattern.

Electrically the heart is vertical.

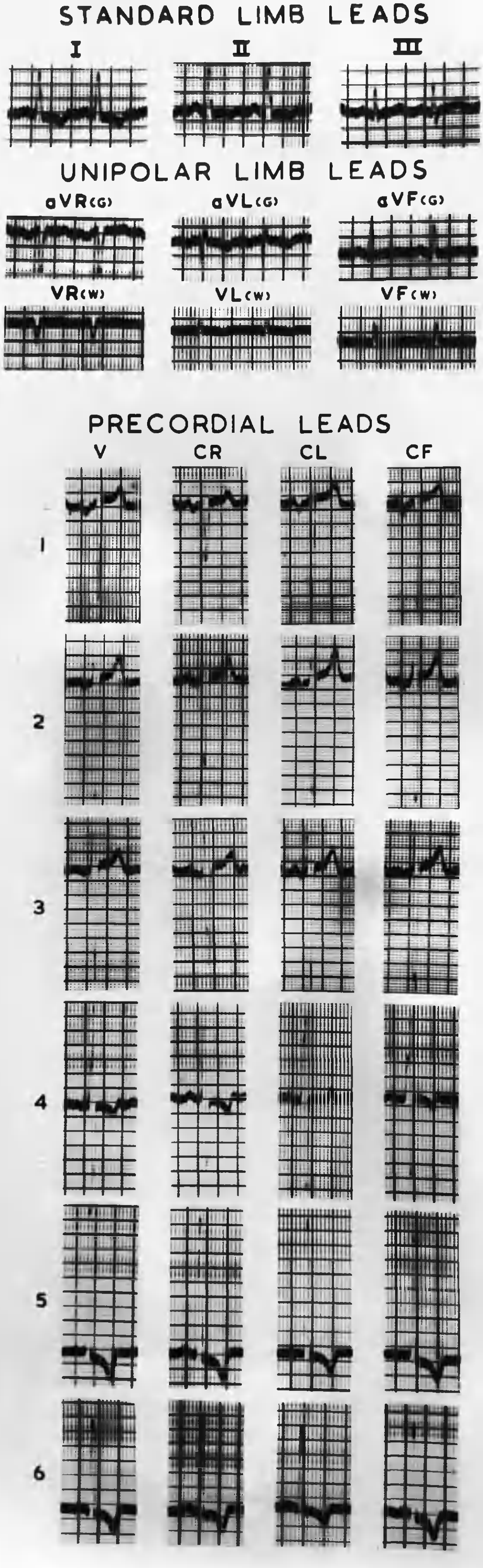
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CF leads, least positive in the CL leads and intermediate in the CR and V leads.

These differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.32 PLATE 60

ABNORMAL. K.C.

Diagnosis: Essential Hypertension. Age 55 years

STANDARD LIMB LEADS.

These show evidence of left ventricular strain.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and upright T waves and an rSr' pattern.

The VL leads have diphasic P and inverted T waves and an rSR' pattern.

The VF leads have upright P and practically flat T waves and a qRs pattern.

Electrically the heart is vertical.

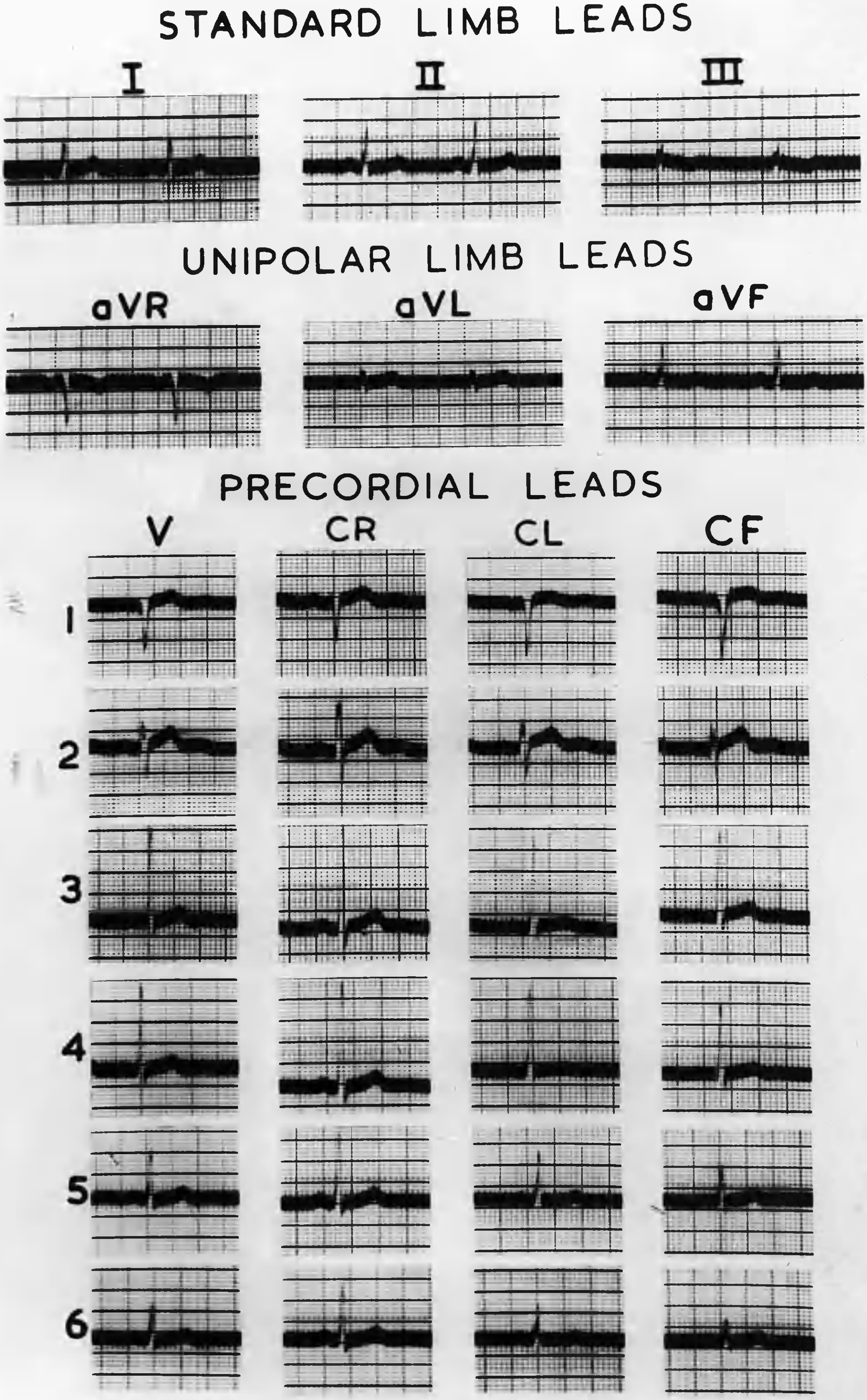
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CL leads, least positive in the CR leads and intermediate in the CF and V leads.

These differences are most obvious in position I and in the transitional zone in position 4, where the T wave is changing from positive to negative.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.33 PLATE 61

ABNORMAL H.McC.

Diagnosis: Chronic Cholecystitis. Age 27 years.

STANDARD LIMB LEADS.

These show a small splintered QRS and inverted T in lead III.

UNIPOLAR LIMB LEADS.

Lead aVR has inverted P and T waves and a Qr pattern.

Lead aVL has practically flat P and upright T waves and a slightly splintered rs pattern.

Lead aVF has upright P and low upright T waves and an Rs pattern.

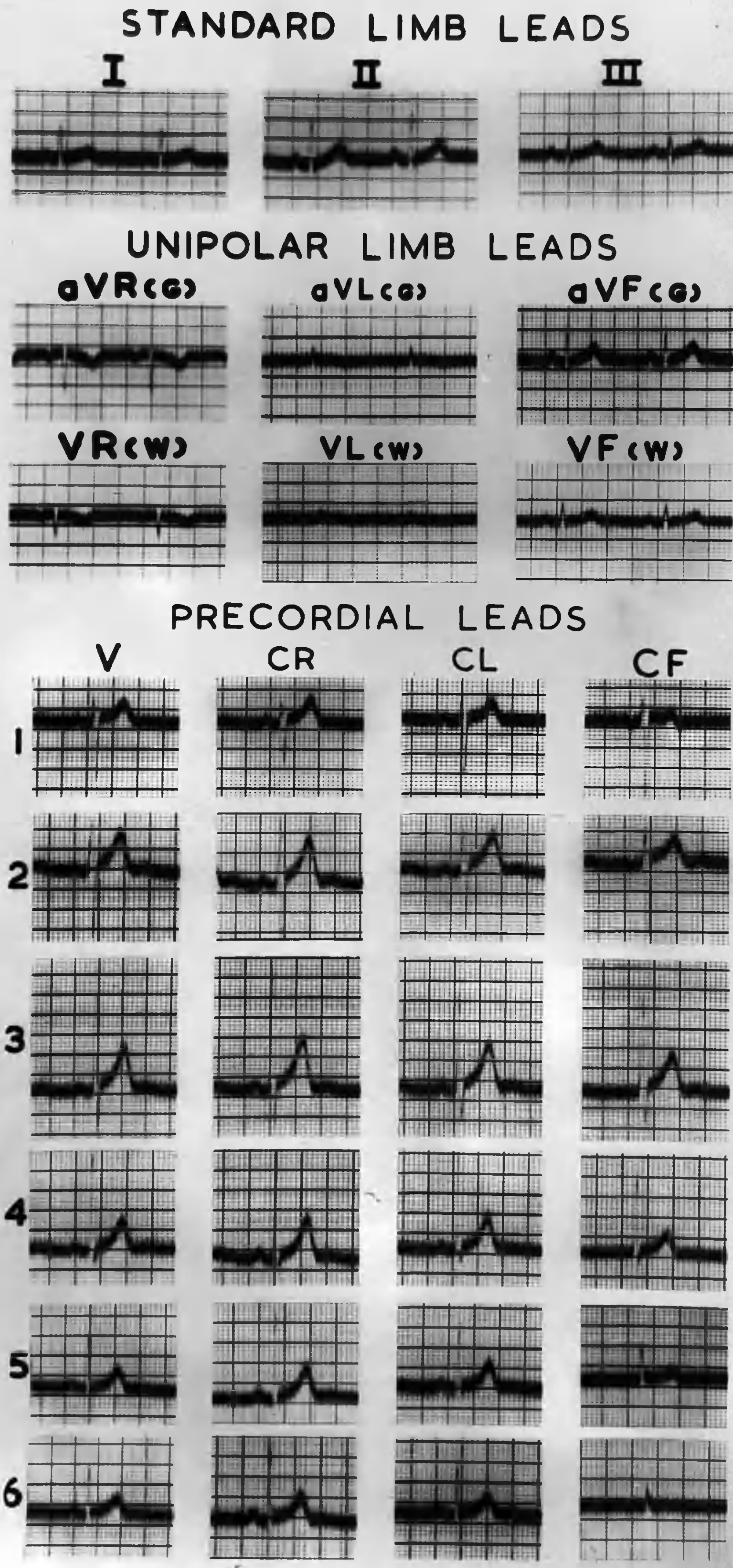
Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S wave in leads over the left precordium is most prominent in CR and least prominent in CL due to the r in aVR and the s in aVL respectively.

T wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 34 PLATE 62

ABNORMAL. J.W.

Diagnosis: Neurocirculatory Asthenia. Age 33 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have shallow inverted P and T waves and an rsr' pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-vertical.

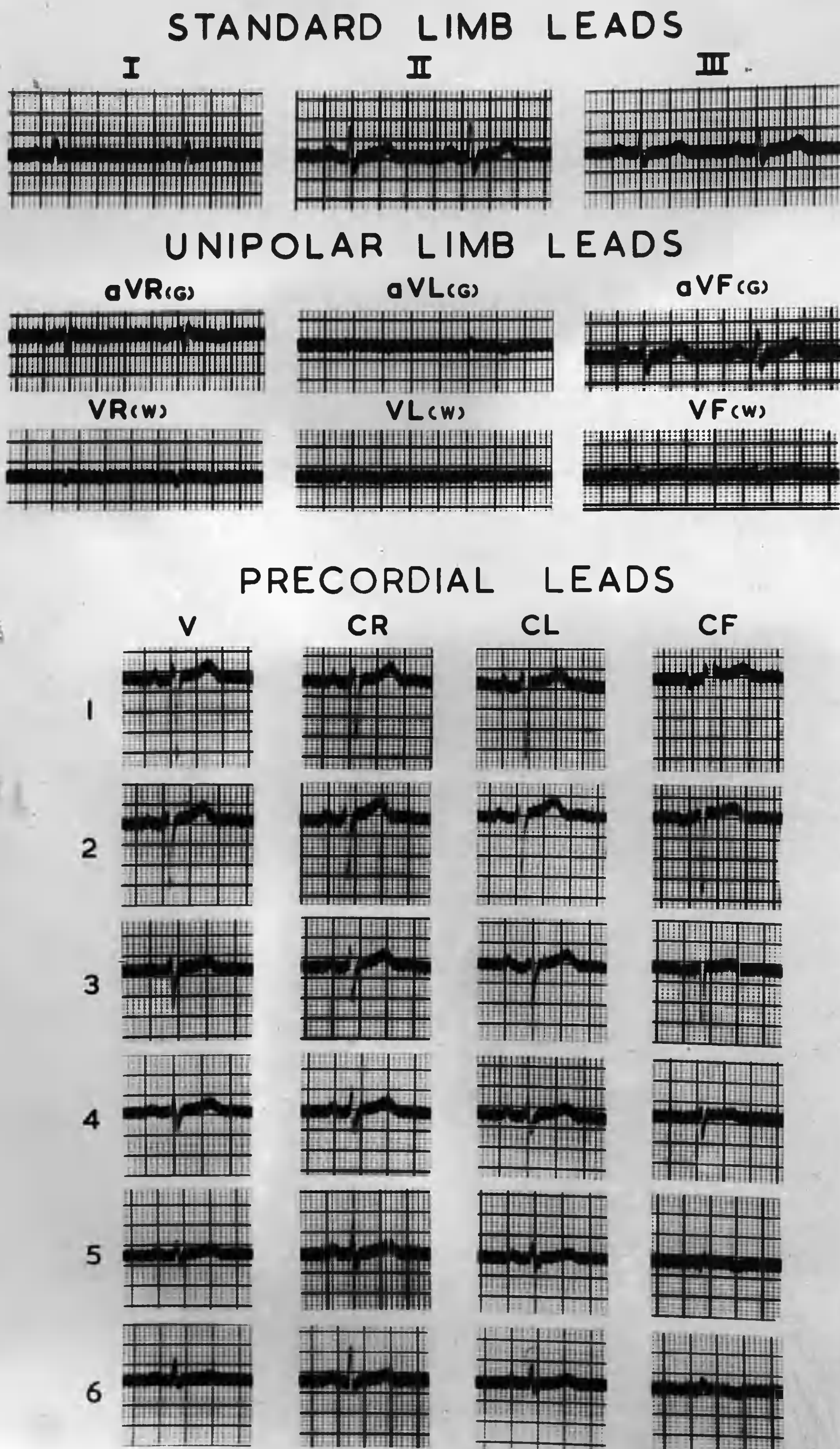
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 35 PLATE 63

ABNORMAL. W.G.

Diagnosis: Left pneumothorax. Age 36 years.

STANDARD LIMB LEADS.

These show slight tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have flat P and shallow inverted T waves and a small vibratory qrsr' pattern.

The VF leads have upright P and T waves and an RS pattern.

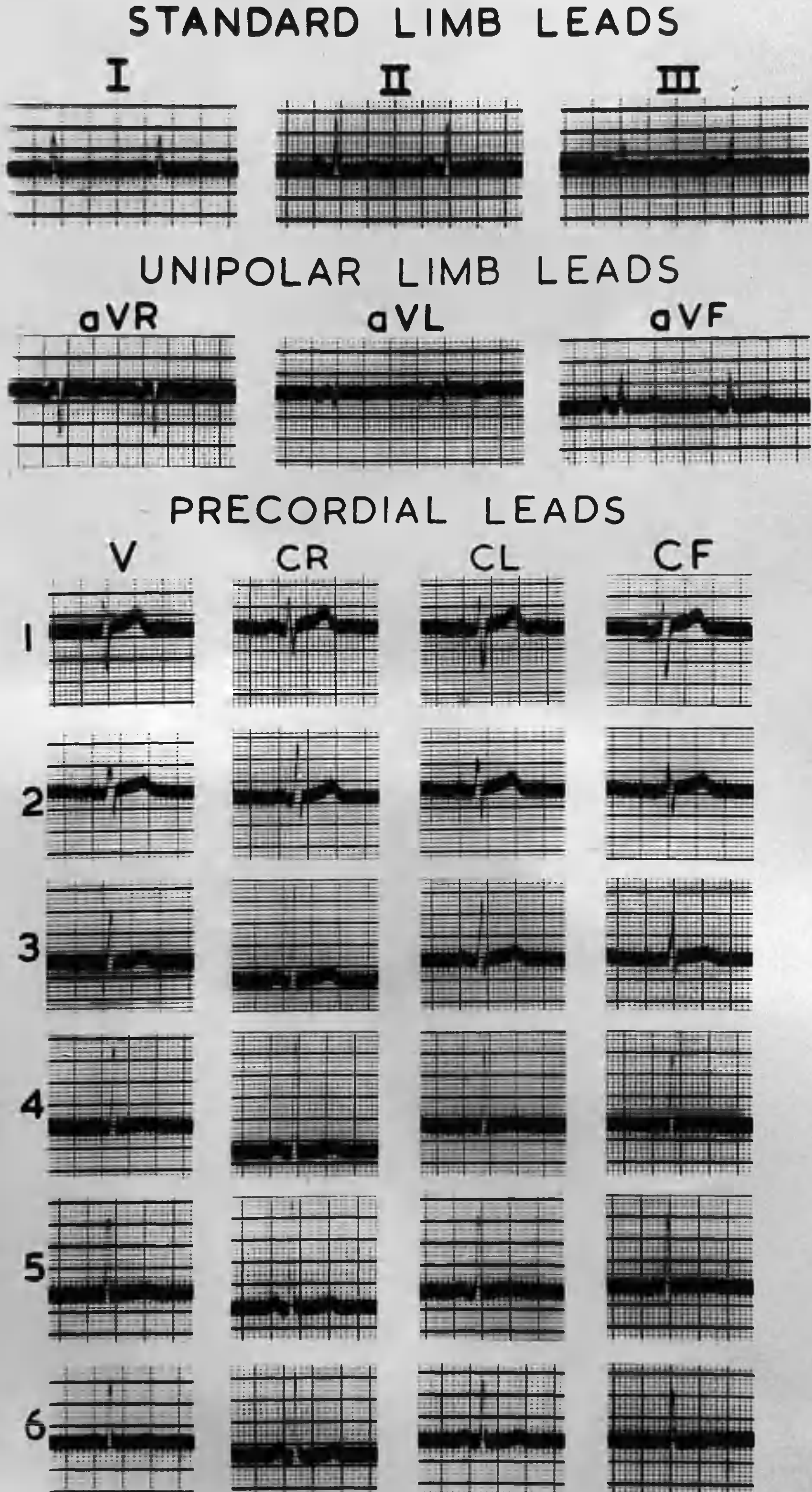
Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S in leads over the left precordium is most prominent in CR due to the r' in VR. Note its absence in CF5 and 6 due to the S in VF which is also responsible for the r' in CFI.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. Note particularly the inversion of T in CF5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 36 PLATE 64

ABNORMAL.

H.McK.

Diagnosis: Chronic Myeloid Leukaemia.

Age 5I years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

Lead aVR has inverted P and shallow inverted T waves and a QS pattern.

Lead aVL has shallow inverted P and T waves and a qr pattern.

Lead aVF has upright P and low upright T waves and an R pattern.

Electrically the heart is semi-vertical.

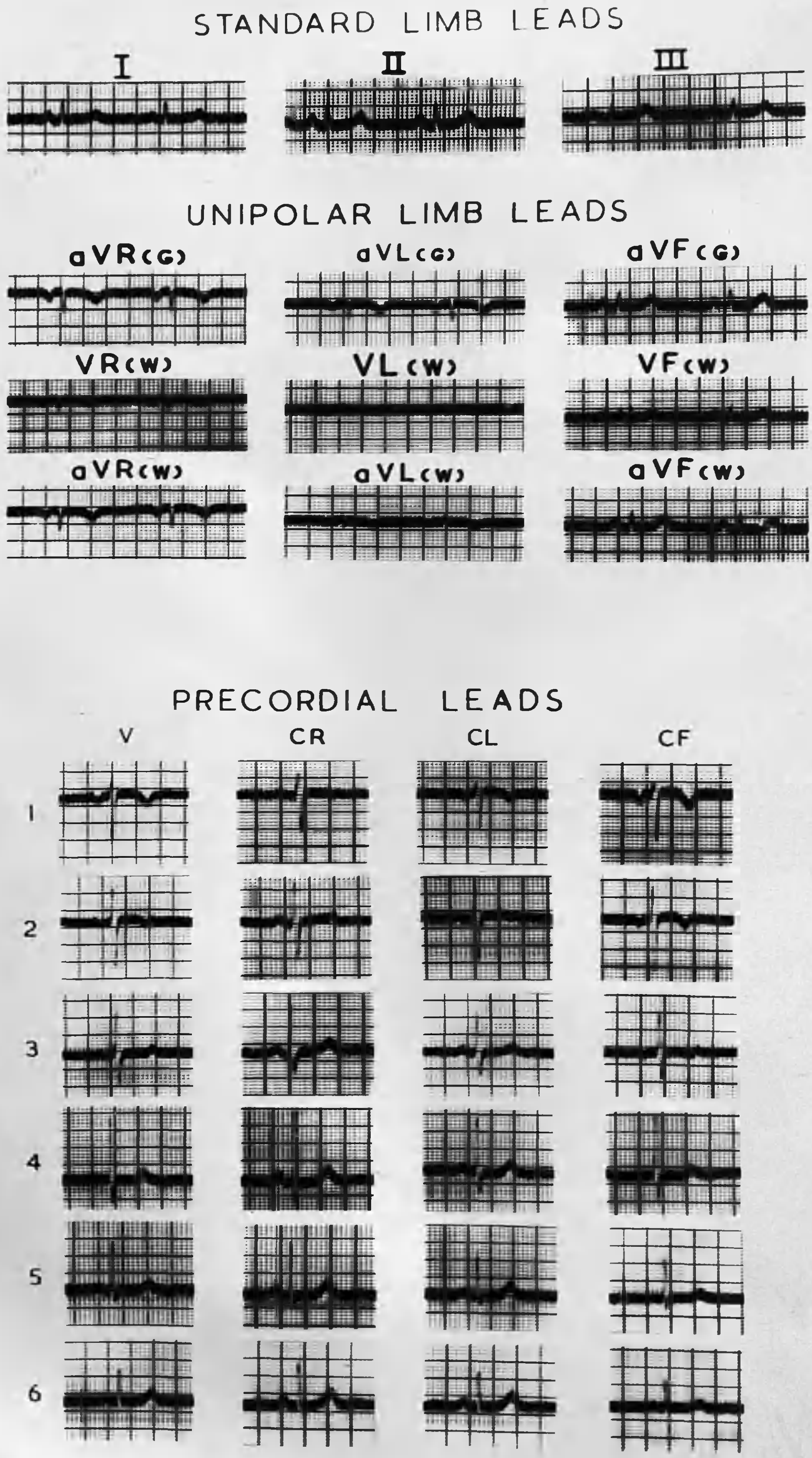
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CL and CR leads, least positive in the CF leads and intermediate in the V leads.

These differences are most obvious in positions I, 5 and 6. In the case of the T waves they are relatively insignificant due to the low amplitude of these waves in the unipolar limb leads.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 37 PLATE 65

ABNORMAL. Miss M.C.

Diagnosis: Post-haemorrhagic Anaemia. Age 52 years

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a QS pattern.

The VL leads have inverted P and T waves and an rsr' pattern.

The VF leads have upright P and T waves and an R pattern.

Electrically the heart is semi-vertical.

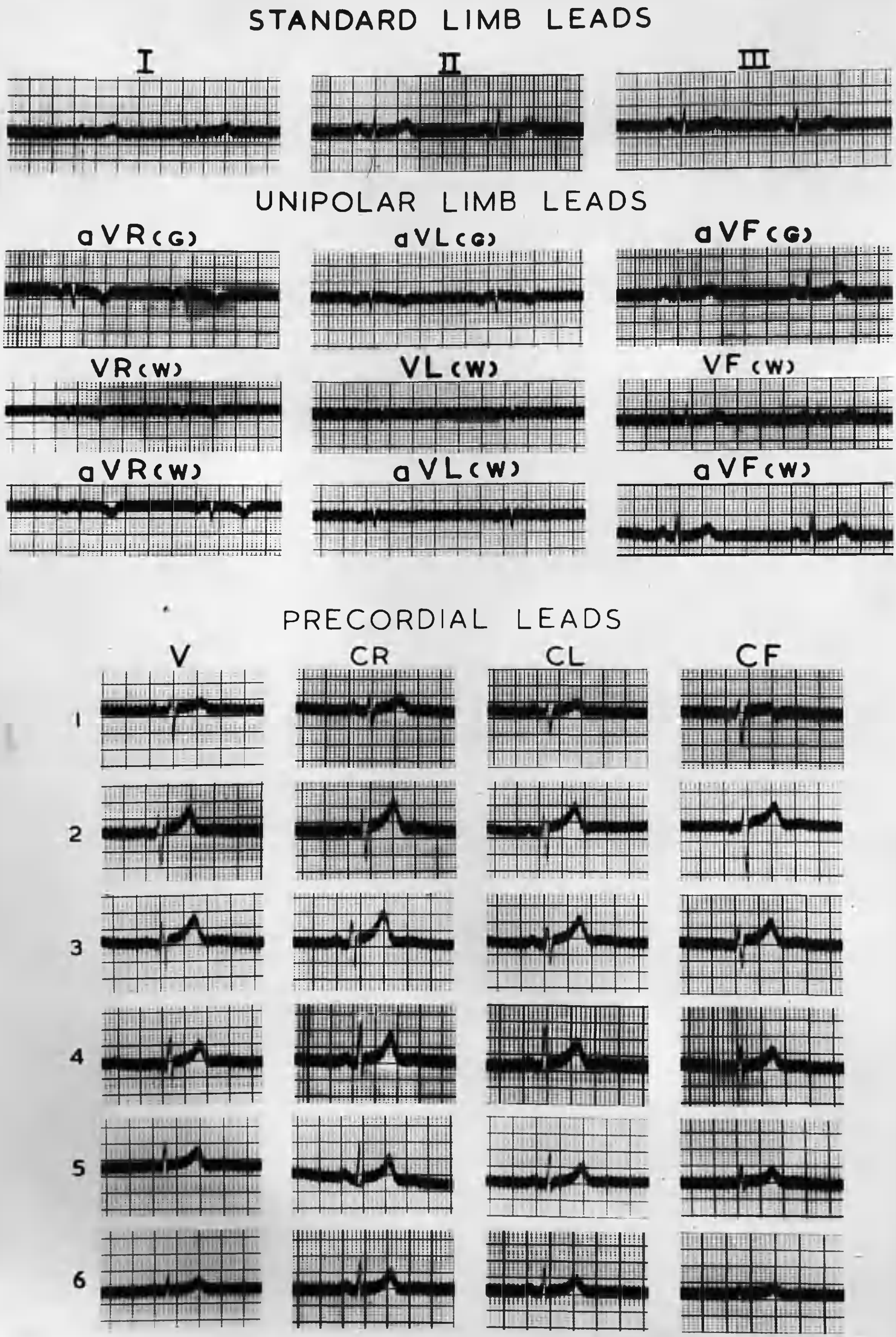
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 2 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 38 PLATE 66

ABNORMAL. J.Y.

Diagnosis: Chronic Bronchitis and Emphysema. Age 57 years.

STANDARD LIMB LEADS.

These show slight tendency to R.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a QS pattern.

The VL leads have inverted P and slightly inverted T waves and an rSr' pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-vertical.

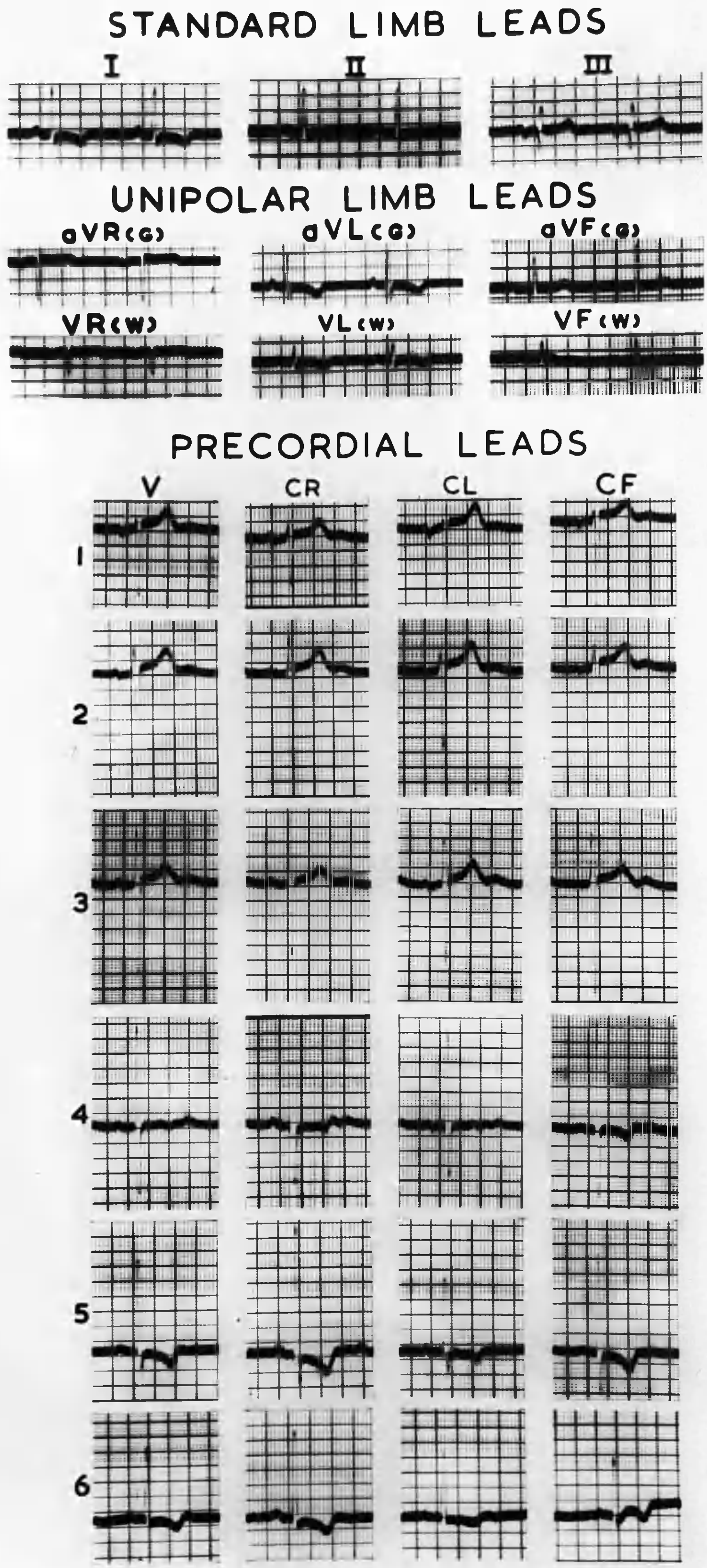
PRECORDIAL LEADS.

P wave: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

The differences are most obvious in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

ABNORMAL. Mrs. E. W.

Diagnosis: Essential Hypertension. Age 54 years

STANDARD LIMB LEADS.

These show appearances suggestive of left ventricular strain and there is a deep Q in lead III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and low upright T waves and an rSr' pattern. There is slight S-T elevation.

The VL leads have upright P and inverted T waves and an Rs pattern. There is slight S-T depression.

The VF leads have low upright P and T waves and a qR pattern. There is no deviation of S-T.

Electrically the heart is in an intermediate position.

PRECORDIAL LEADS.

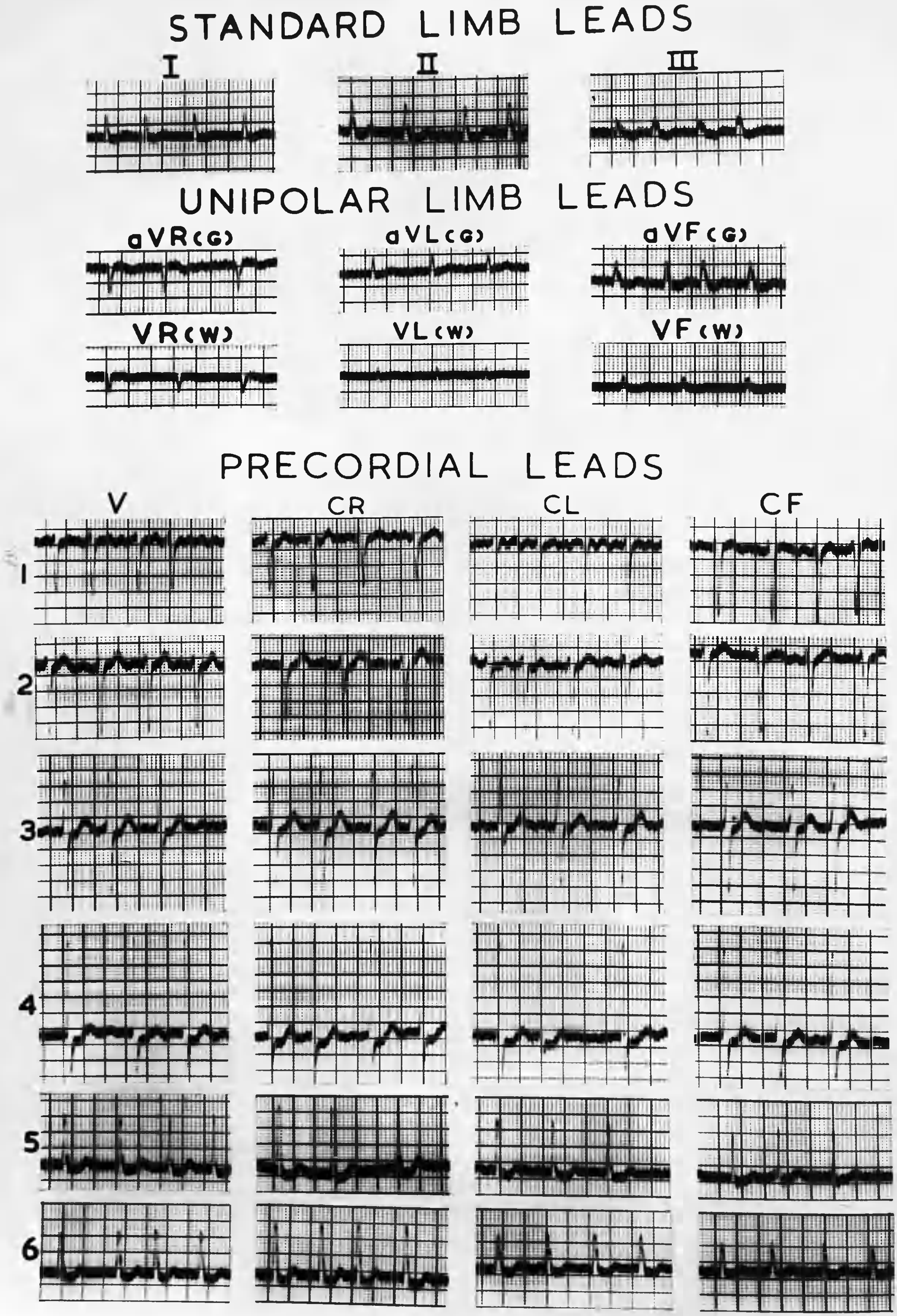
P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

T wave: this is most positive in the CL leads, least positive in the CR leads and intermediate in the CF and V leads.

S-T segment: this is most positive in the CL leads, least positive in the CR leads and intermediate in the CF and V leads.

These differences are most obvious in positions 4 and 5 where the T wave and S-T segment are changing in direction.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.40 PLATE 68

ABNORMAL. Miss E.C.

Diagnosis: Thyrotoxicosis: Auricular Fibrillation. **Age** 56 years.

STANDARD LIMB LEADS.
These show no axis deviation.

UNIPOLAR LIMB LEADS.
The VR leads have an rS pattern. There is slight S-T elevation and the T waves are shallow and inverted.

The VL leads have a qRs pattern and low upright T waves. There is no S-T deviation.

The VF leads have a qR pattern. There is slight S-T depression and the T waves are low upright.

Electrically the heart is in the intermediate position.

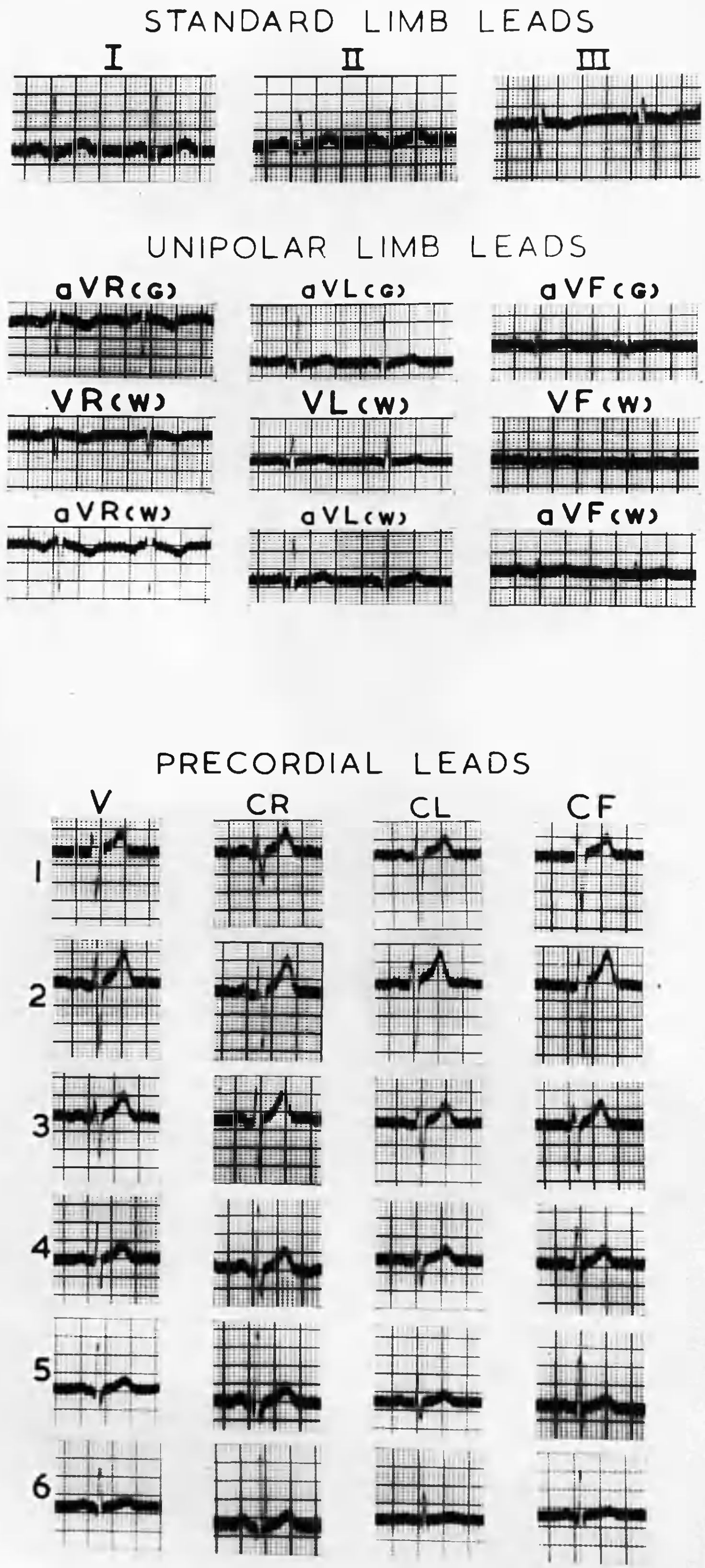
PRECORDIAL LEADS.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

S-T interval: this is most positive in the CF leads, least positive in the CR leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

These differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 41 PLATE 69

ABNORMAL. R.P.

Diagnosis: Obesity. Age 28 years.

STANDARD LIMB LEADS.

These show L.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have upright P and T waves and a qRs pattern.

The VF leads have upright P and T waves and a qrs pattern.

Electrically the heart is semi-horizontal.

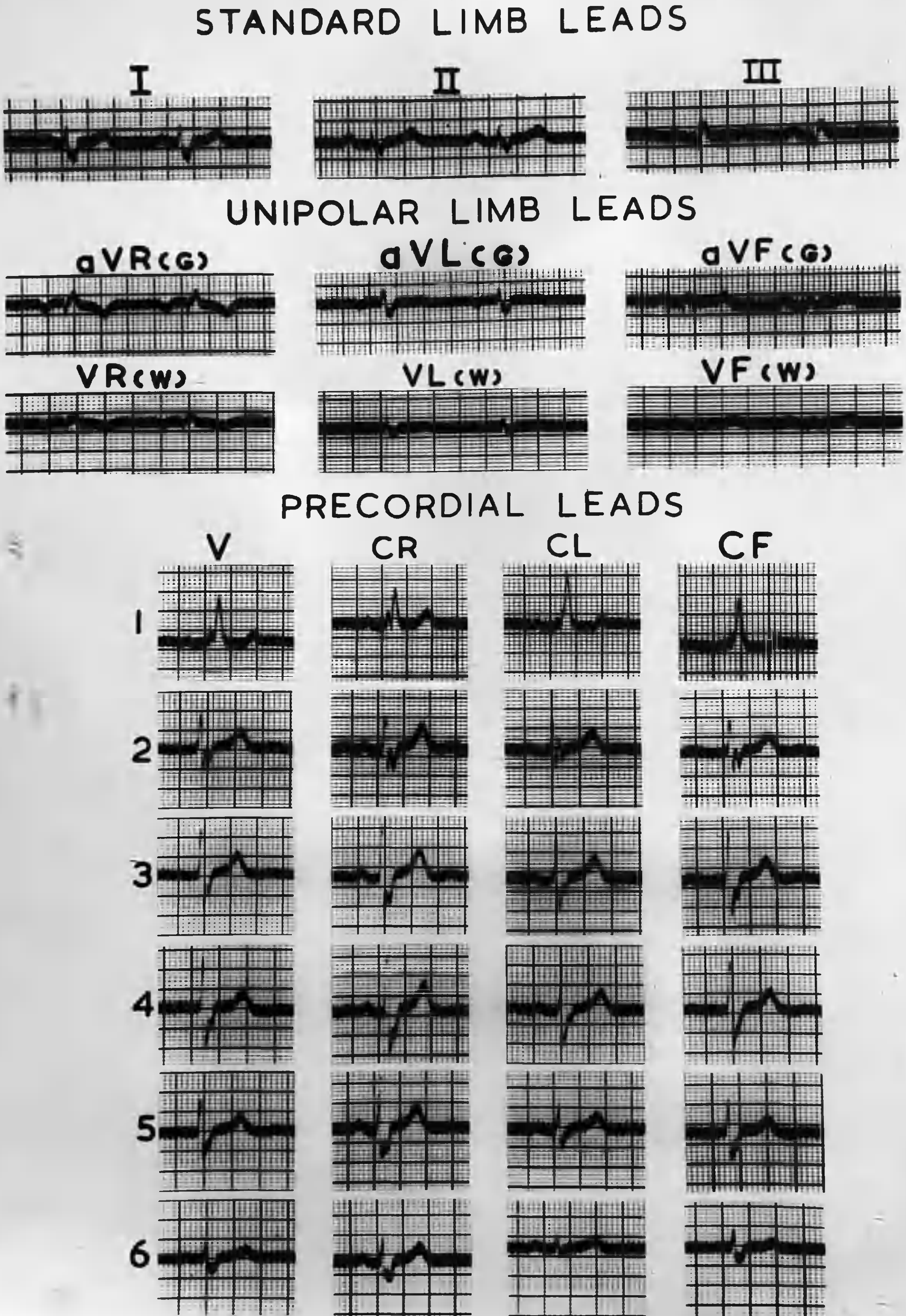
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

These differences are most obvious in positions I, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR (G)
aVL (G)
aVF (G)
VR (W)
VL (W)
VF (W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.42 PLATE 70

ABNORMAL. R.R.

Diagnosis: Chronic Coronary Artery Disease: Right Bundle Branch Block.

Age 6I years.

STANDARD LIMB LEADS.

These show the pattern of right bundle branch block.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a broad QR pattern.

The VL leads have shallow inverted P and low upright T waves and a broad RS pattern.

The VF leads have upright P and T waves and a small vibratory qrs pattern.

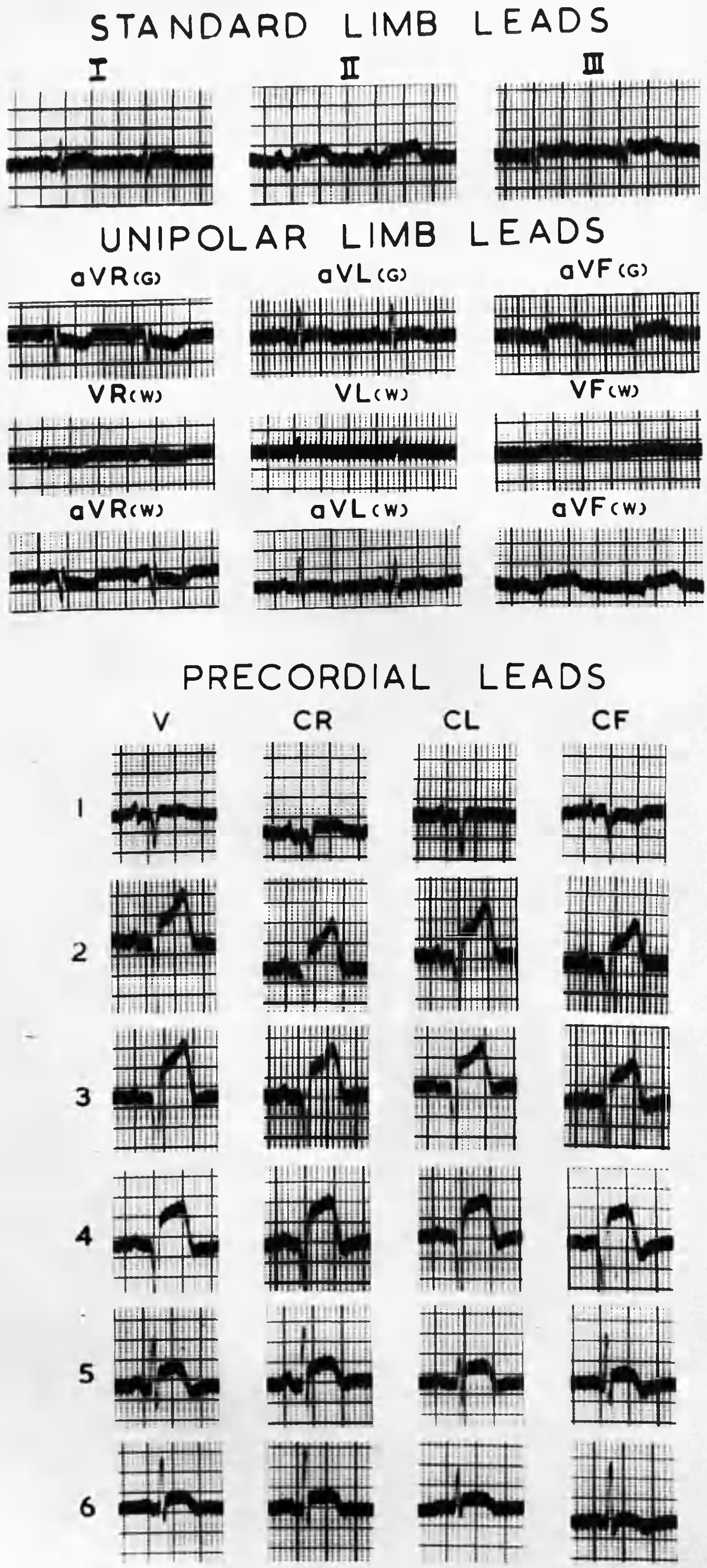
Electrically the heart is semi-horizontal.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: the basic pattern in positions I,2 and 3 is a "W"-shaped complex. The first spike of this "W" which after position I becomes the R wave in all leads, is most prominent in CR and least prominent in CL due to the Q in VR and the R in VL respectively. The second spike which after positions I and 2 is incorporated in the broad S wave in all leads, is most positive in CL and least positive in CR due to the broad S in VL and the broad R in VF respectively. The CF and V leads are intermediate with regard to these appearances.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

ABNORMAL. R.I.

Diagnosis: Myocardial Infarction (Anterior) Age 65 years.

STANDARD LIMB LEADS.

These show L.A.D. There is S-T elevation in all leads.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern. There is S-T depression.

The VL leads have upright P and low upright T waves and a qRs pattern. There is very slight S-T elevation.

The VF leads have practically flat P and upright T waves and a small rs pattern. There is S-T elevation.

Electrically the heart is semi-horizontal.

PRECORDIAL LEADS.

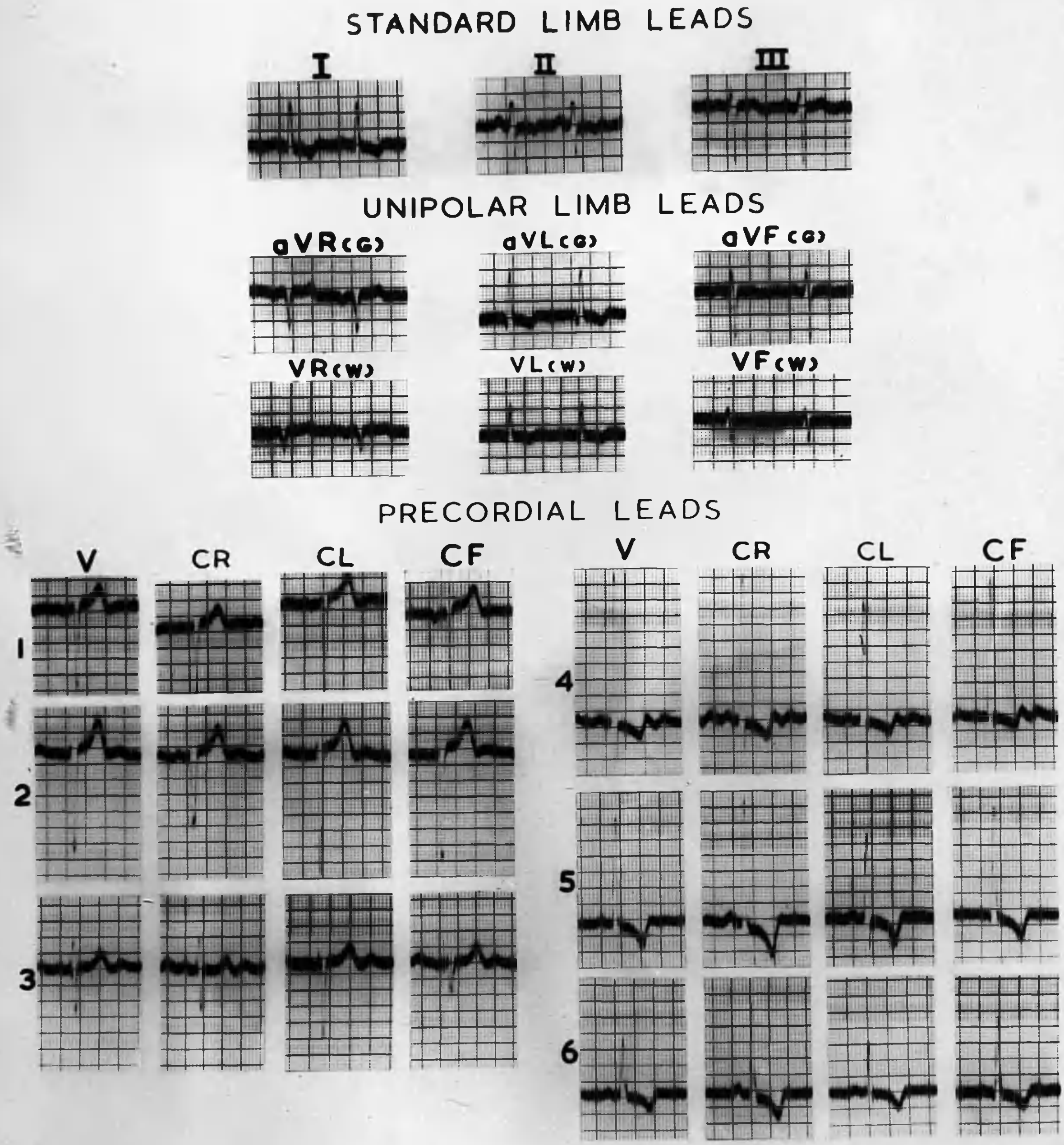
P wave: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads. The S in leads over the left precordium is most prominent in CR due to the r' in VR.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

S-T interval: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are particularly well seen in positions I and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.44 PLATE 72

ABNORMAL. R.R.

Diagnosis: Malignant Hypertension. Age 34 years.

STANDARD LIMB LEADS.

These show the appearances of left ventricular strain with obvious L.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and upright T waves and a QS pattern.

The VL leads have practically flat P and inverted T waves and a qR pattern.

The VF leads have upright P and practically flat T waves and an rS pattern.

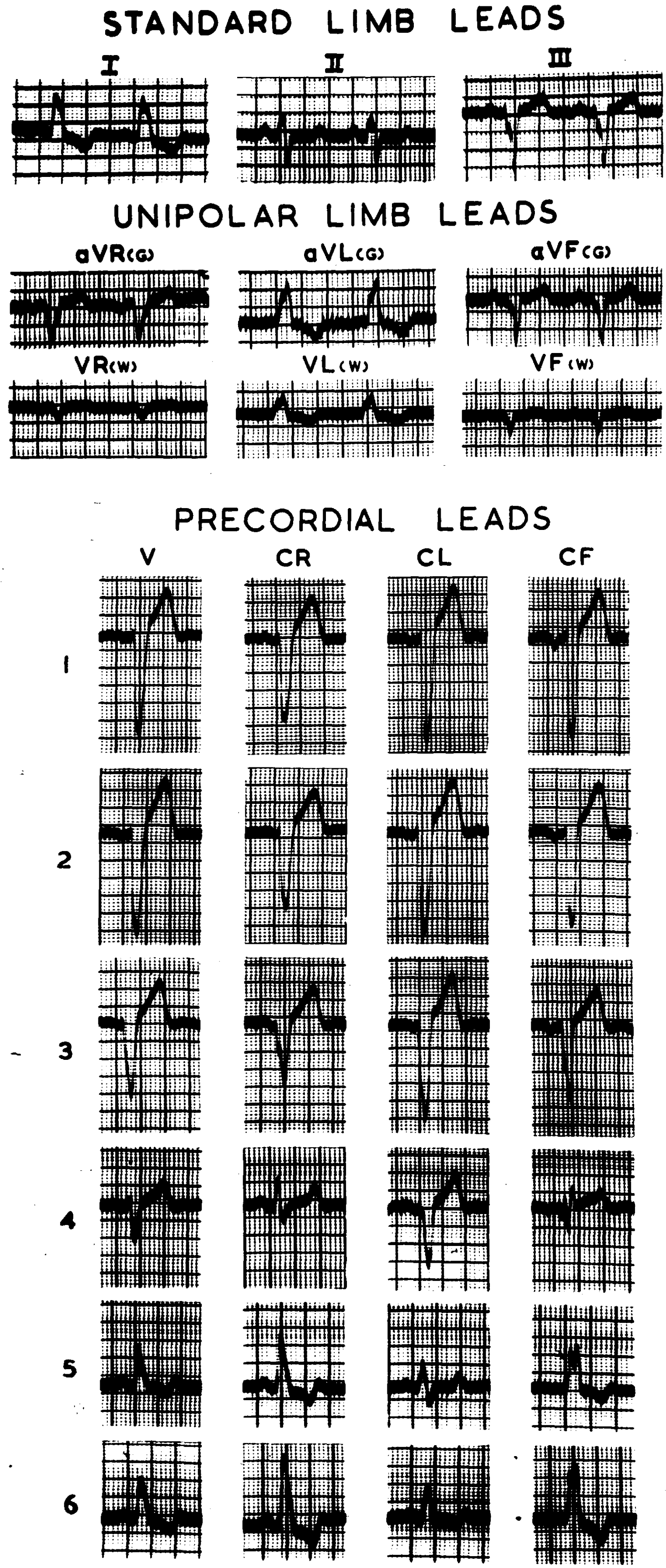
Electrically the heart is horizontal.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR and CF leads, least positive in the CL leads and intermediate in the V leads. Note the q in CF5 and 6 due to the initial r in VF.

T wave: this is most positive in the CL leads, least positive in the CR leads and intermediate in the CF and V leads.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.45 PLATE 73

ABNORMAL. T.A.

Diagnosis: Essential Hypertension: Left Bundle Branch Block. Age 47 years.

STANDARD LIMB LEADS.

These show L.A.D. and left bundle branch block.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and upright T waves and a wide QS pattern.

The VL leads have practically flat P and inverted T waves and a wide splintered R pattern.

The VF leads have upright P and T waves and a wide splintered QS pattern.

Electrically the heart is horizontal.

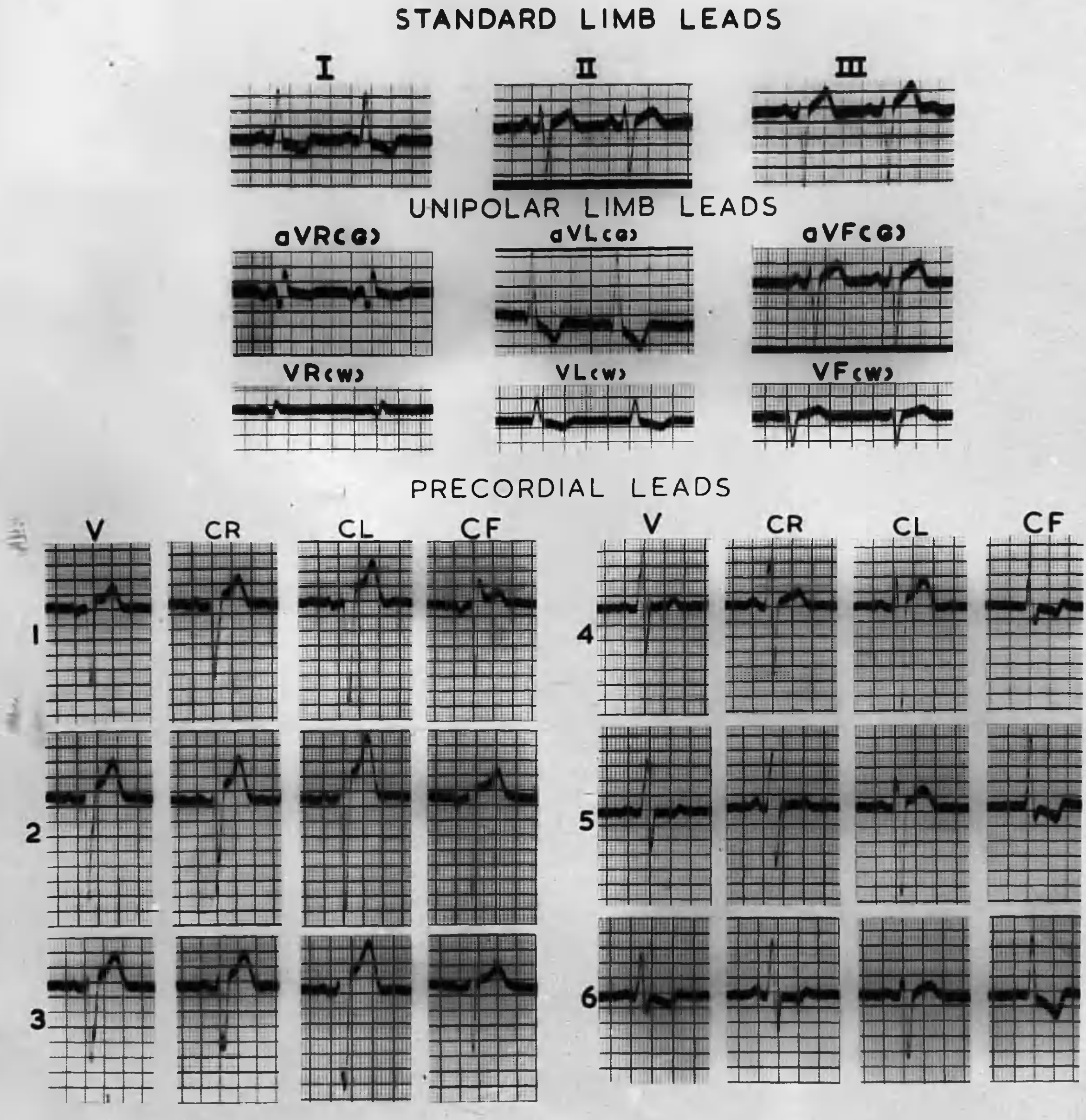
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CL leads, least positive in the CR and CF leads and intermediate in the V leads.

These differences are most obvious in the transitional zone (positions 4 and 5) where both the QRS complex and the T wave are changing in direction.



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.46 PLATE 74

ABNORMAL. J.T.

Diagnosis: Chronic Coronary Artery Disease: Left Bundle Branch Block. Age 47 years

STANDARD LIMB LEADS.

These show the appearances of left bundle branch block.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and shallow inverted T waves and a broad QR pattern.

The VL leads have practically flat P and inverted T waves and a broad qR pattern. There is S-T depression.

The VF leads have upright P and T waves and a broad rS pattern. There is S-T elevation.

Electrically the heart is horizontal.

PRECORDIAL LEADS.

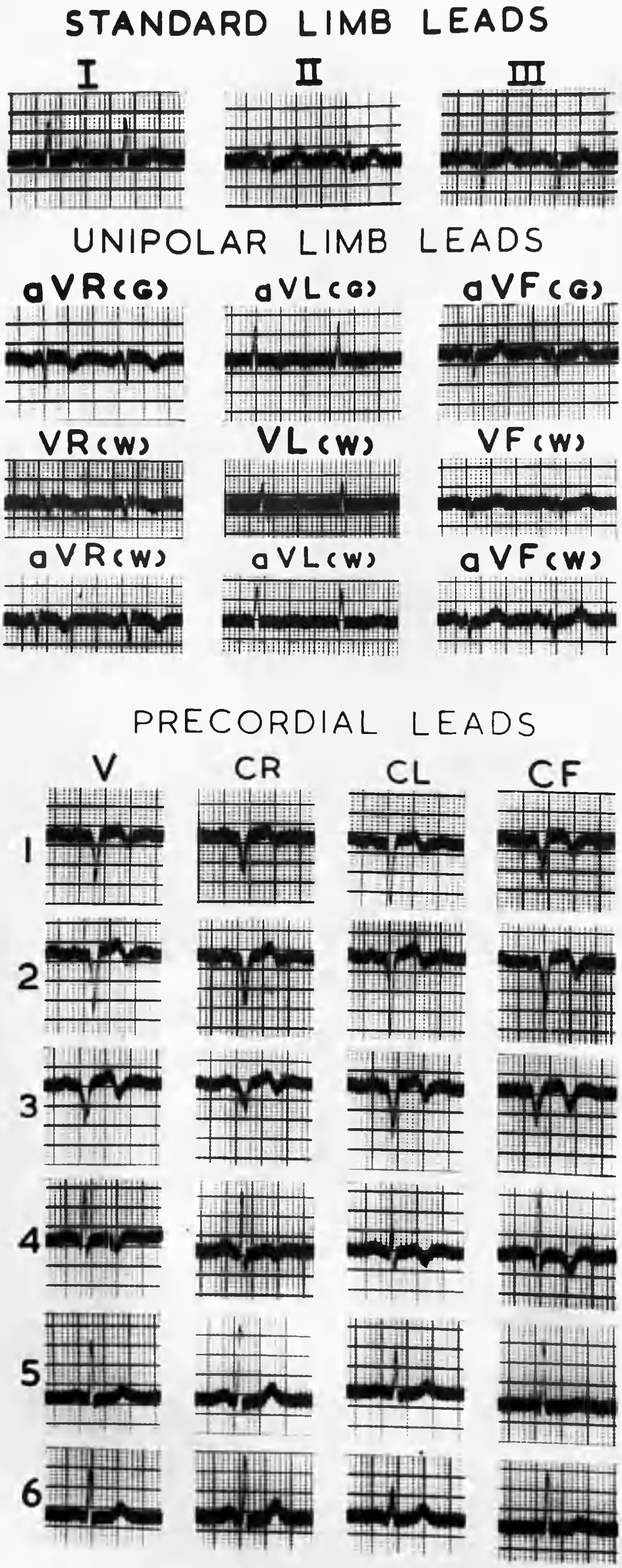
P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CF leads, least positive in the CL leads and intermediate in the CR and V leads.

T wave: this is most positive in the CL leads, least positive in the CF leads and intermediate in the CR and V leads.

S-T segment: this is most positive in the CL leads, least positive in the CF leads and intermediate in the CR and V leads.

These differences are most obvious in positions 4, 5 and 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.47 PLATE 75

ABNORMAL. A.W.

Diagnosis: Myocardial Infarction: (anterior) Age 54 years.

STANDARD LIMB LEADS.

These show L.A.D..

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have practically flat P waves and shallow diphasic T waves and a qR pattern.

The VF leads have upright P and T waves and an rS pattern.

Electrically the heart is horizontal.

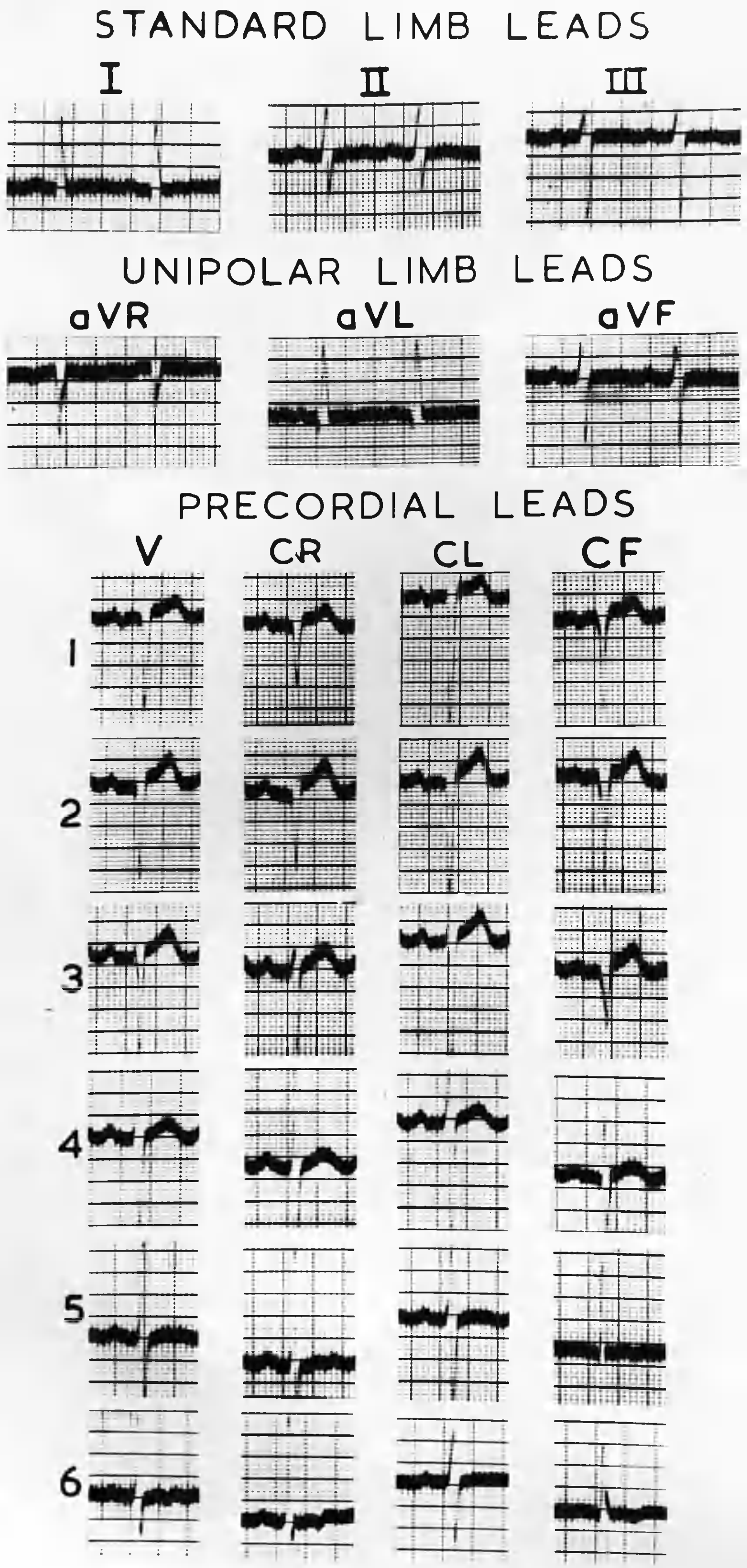
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR and CF leads, least positive in the CL leads and intermediate in the V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious at the edges of the infarct in positions I, 4 and 5 where the T waves are changing direction.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 48 PLATE 76

ABNORMAL Mrs. C.C.

Diagnosis: Essential Hypertension. Age 68 years

STANDARD LIMB LEADS.

These show L.A.D.

UNIPOLAR LIMB LEADS.

Lead aVR shows inverted P and practically flat T waves and a QS pattern.

Lead aVL shows upright P and shallow inverted T waves and a qR pattern.

Lead aVF shows upright P and practically flat T waves and an RS pattern.

Electrically the heart is horizontal.

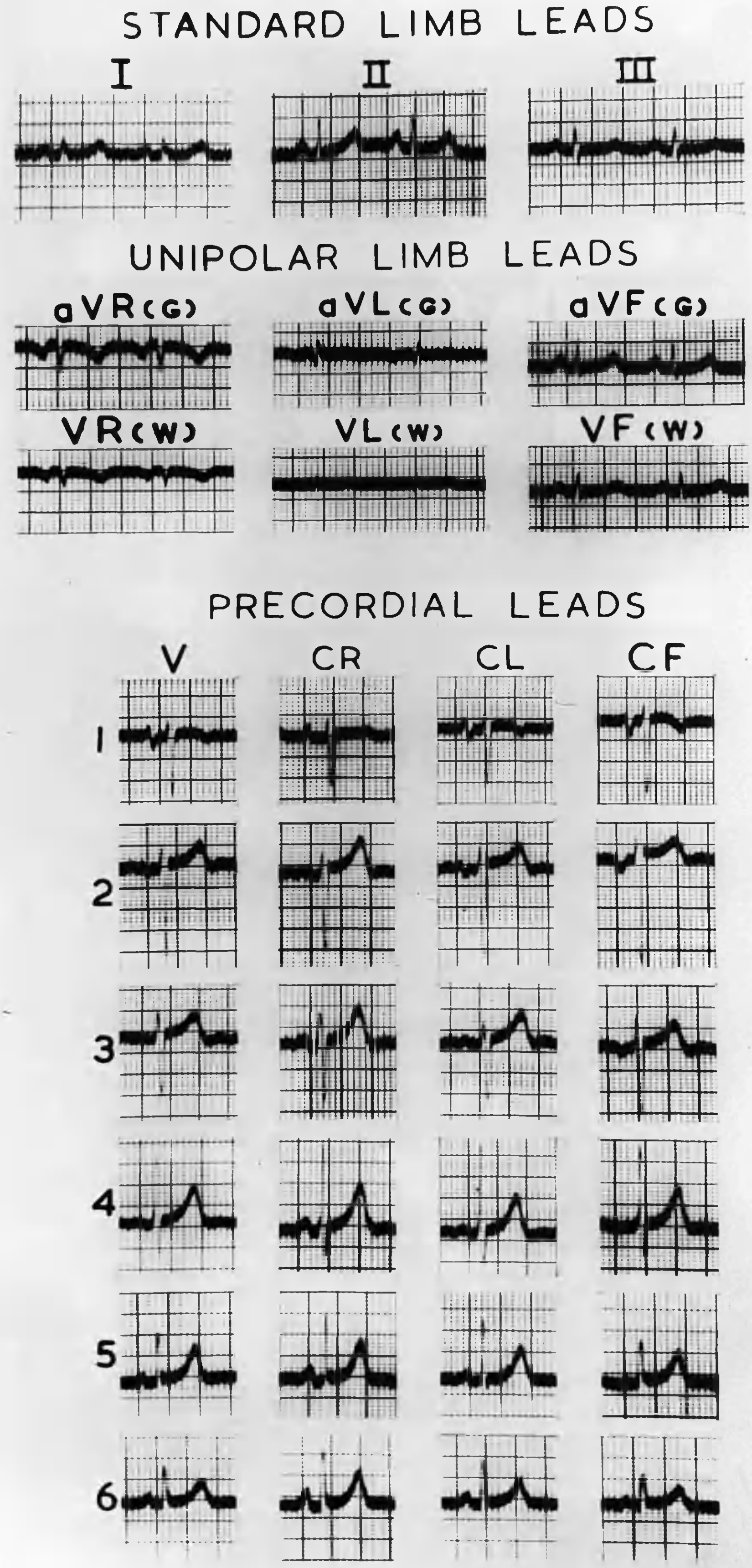
PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CL leads, least positive in the CF and CR leads and intermediate in the V leads.

The differences in the QRS complexes are obvious in all positions due to the large amplitudes of these deflections in the unipolar limb leads. The differences in the T wave on the other hand are slight in both the unipolar limb leads and the precordial leads; they are most obvious in position 6.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 49 PLATE 77

ABNORMAL. Miss R.McD.

Diagnosis: Mitral Stenosis. Age 34 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a QS pattern.

The VL leads have practically flat P and T waves and a qr pattern.

The VF leads have upright P and T waves and an Rs pattern.

The electrical position of the heart is indeterminate.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

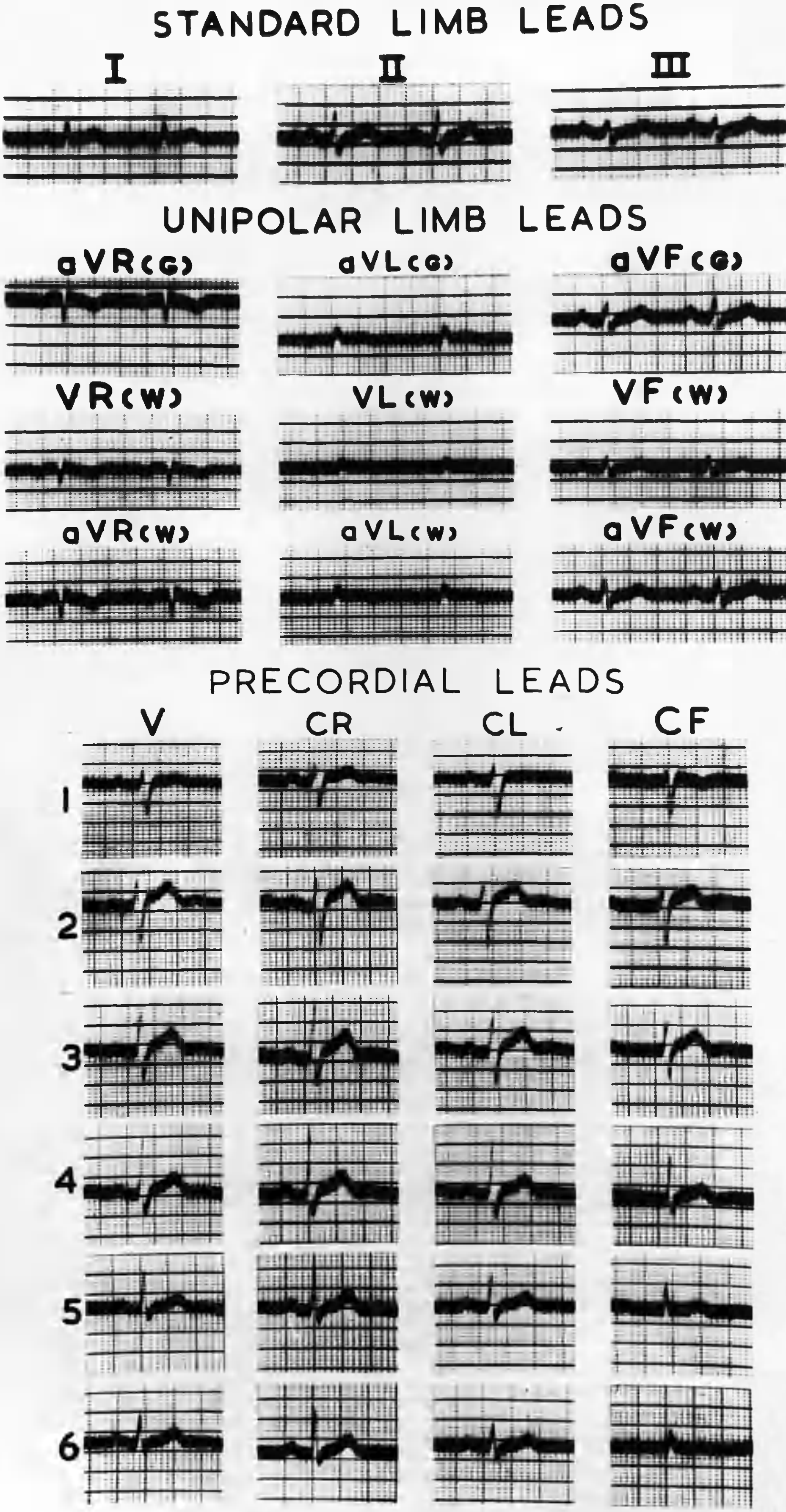
T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.

PART I.

Section 9.

Plates 78 to 90.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.I PLATE 78a

NORMAL.

W.A.

Age 36 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have practically flat P and T waves and a qr pattern.

The VF leads have upright P and T waves and an RS pattern.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S in leads over the left precordium is least prominent in CF due to the S in VF.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from Rs to rs to rS.

CL leads: these resemble the V leads fairly closely.

CF leads: these show progression from qr to Qr to QS to rS.

V leads: these show progression intermediate between the extremes of the CR and CF leads, from qRs to qrs to qs to rs to rS.

Comparison of T wave patterns.

CR leads: T remains positive throughout.

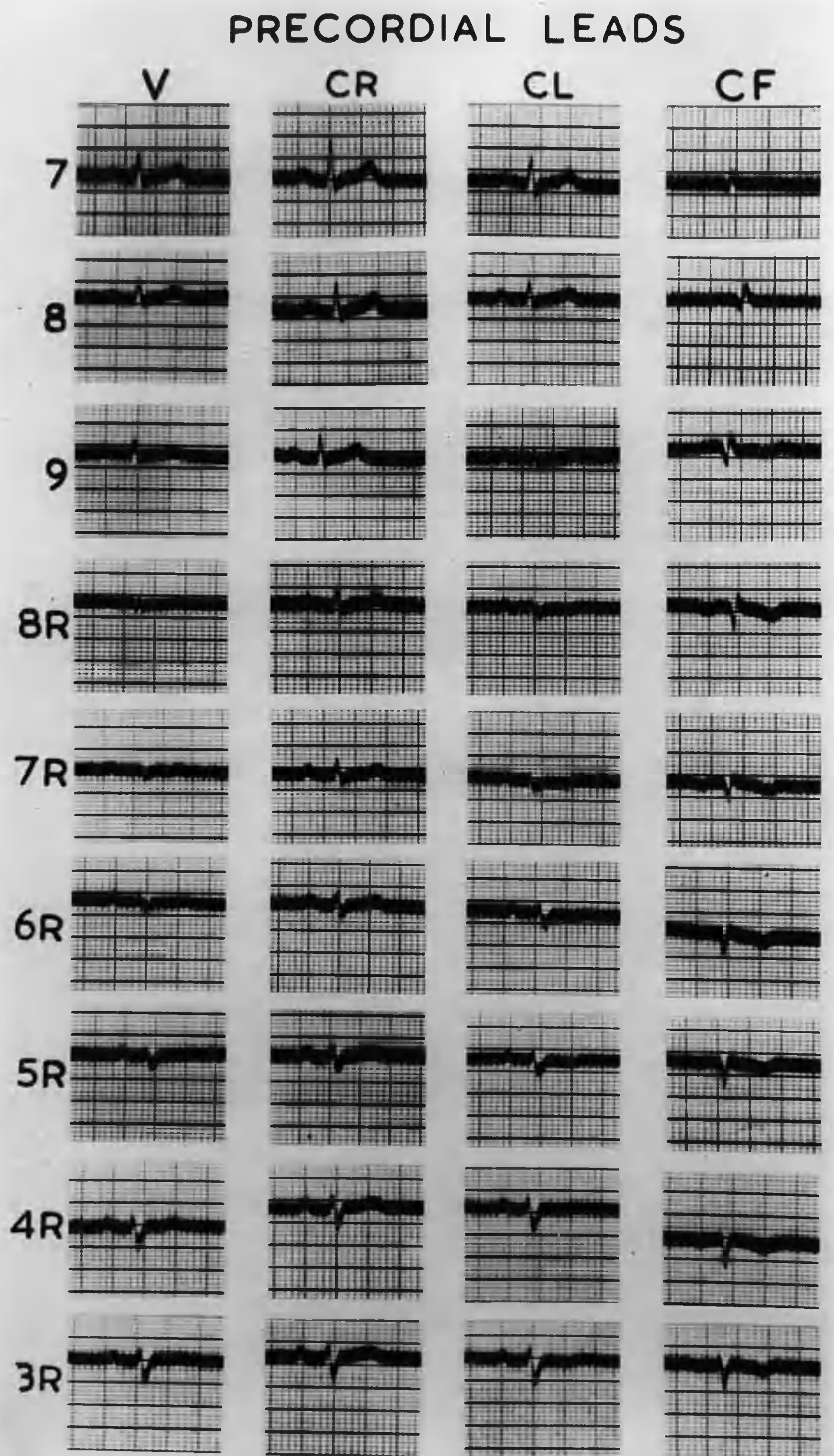
CL leads: these resemble the V leads fairly closely but are slightly less positive.

CF leads: T is flat in positions 7 and 8 and negative in positions 9 to 3R.

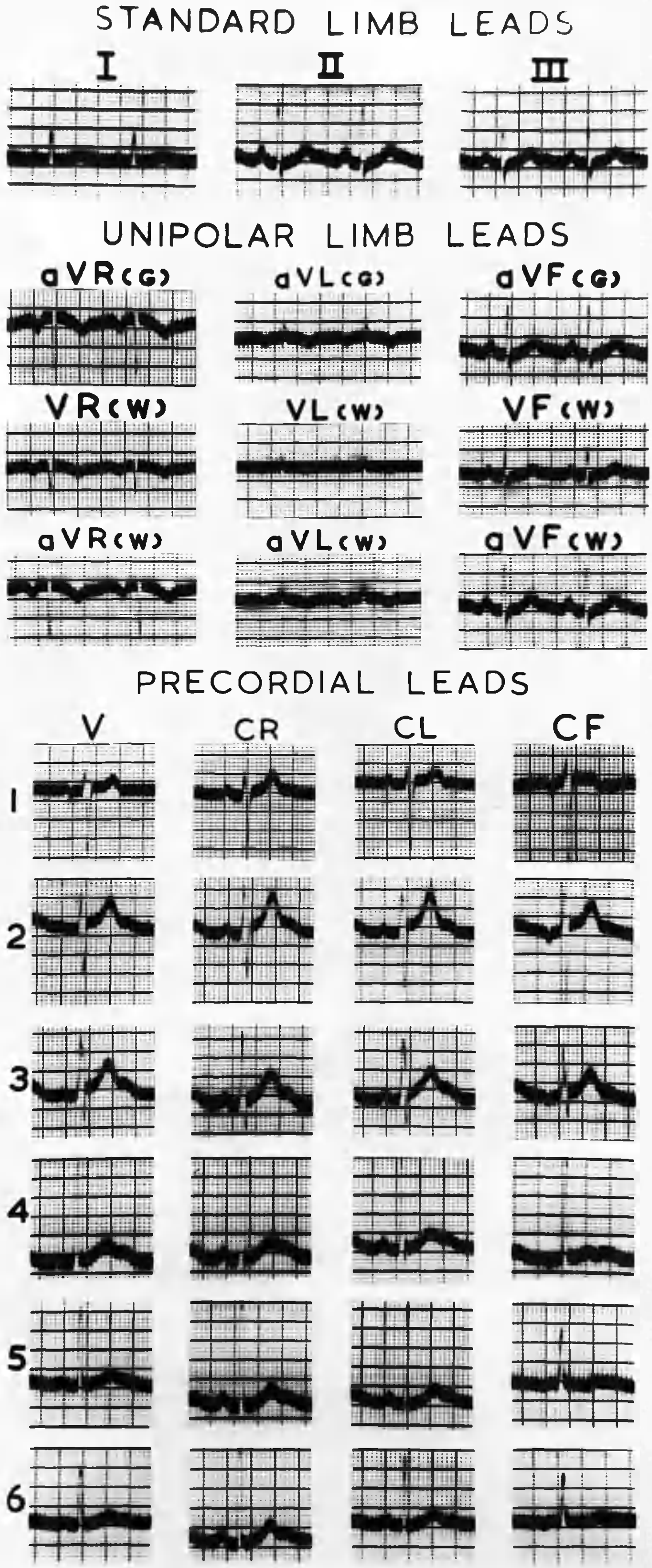
V leads: T is intermediate between CR and CF being slightly positive or flat throughout.

A noteworthy feature is the complete absence of a Q wave in the CR leads. This is due to the initial Q in VR.

In position 7R the CF lead is almost an exact inversion of the CR lead.



PRECORDIAL LEADS
V
CR
CL
CF
7
8
9
8R
7R
6R
5R
4R
3R


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

NORMAL.

D.McK.

Age 38 years.

STANDARD LIMB LEADS.

These show no axis deviation. There are prominent U waves, particularly in leads II and III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern. There is an inverted U wave.

The VL leads have slightly inverted P and T waves and an rsr' pattern. There is no obvious U wave.

The VF leads have upright P and T waves and an Rs pattern. There is an upright U wave.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR and CL leads, least positive in the CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

U wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.

PLATE 79b

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns:

CR leads: these show progression from qR to R to Rs to rS.

CL leads: these resemble the **V** leads fairly closely.

CF leads: these show progression from qR to QR to Qr to QS to rS.

V leads: these show progression intermediate between the extremes of the CR and CF leads from qR to qr to qs to rs to rS.

Comparison of T wave patterns.

CR leads: T remains positive throughout.

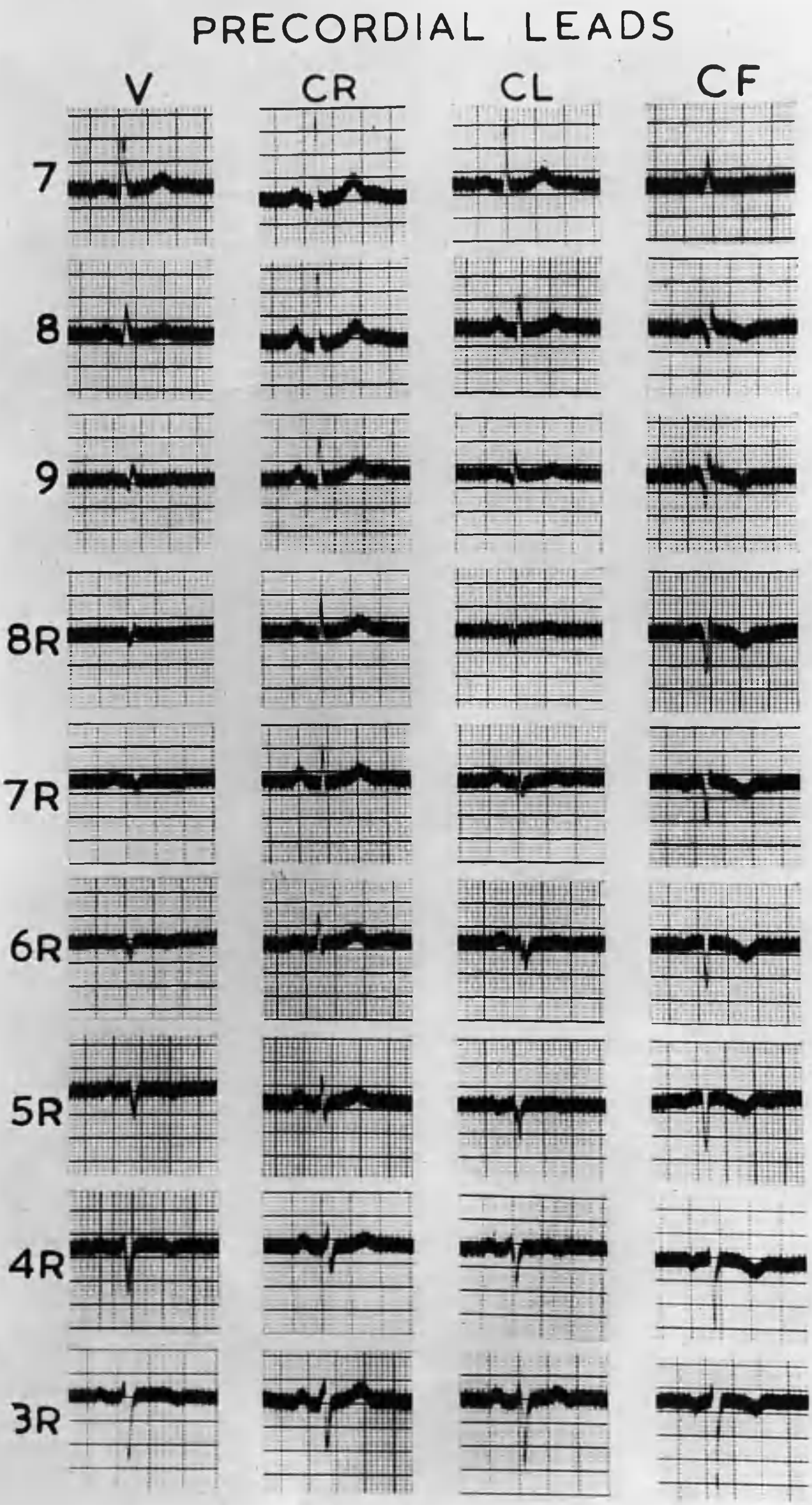
CL leads: these resemble the V leads fairly closely but are slightly more positive.

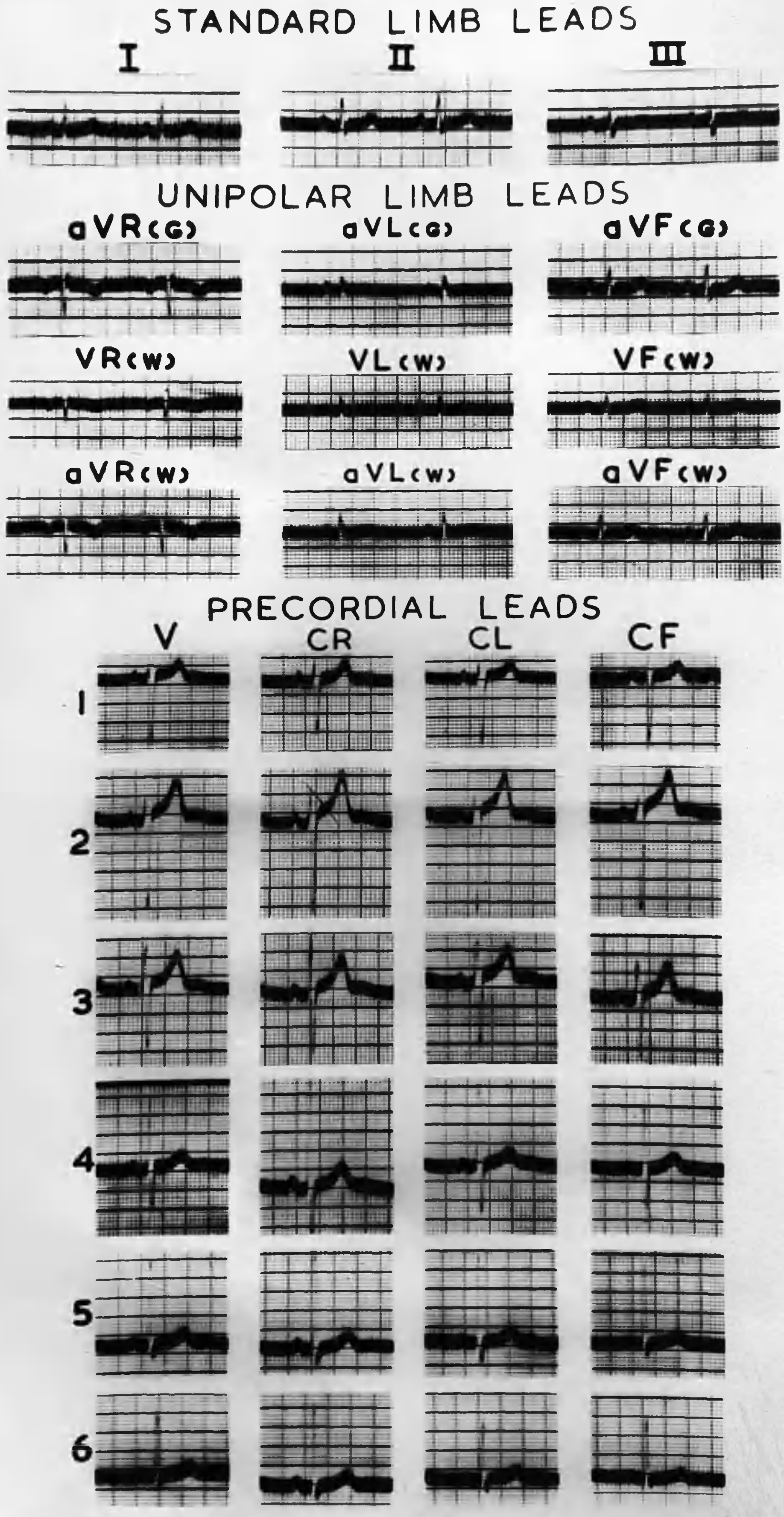
CF leads: **T** is negative in positions 8 to 3R.

V leads: T is intermediate between the extremes of the CR and CF leads, being positive in positions 7 to 9, flat in 8R and 7R and slightly negative in 6R to 3R.

A noteworthy feature is the absence of a significant Q or QS type of pattern in the CR leads. This is due to the initial Q in VR.

In position 7R the CF lead is almost an exact inversion of the CR lead.


PRECORDIAL LEADS
V
CR
CL
CF
7
8
9
8R
7R
6R
5R
4R
3R


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO.3 PLATE 80a

NORMAL. A.H.

Age 62 years.

STANDARD LIMB LEADS.

These show a tendency to L.A.D.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have low upright P and T waves and a qR pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-horizontal.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I and 6.

PLATE 80b

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from Rs to R to r to rs to rS.

CL leads: these resemble the V leads fairly closely.

CF leads: these show progression from qR to QR to Qr to QS to rS.

V leads: these show progression intermediate between the extremes of the CR and CF leads, from qR to qr to qs to rS.

Comparison of T wave patterns:

CR leads: T remains positive throughout.

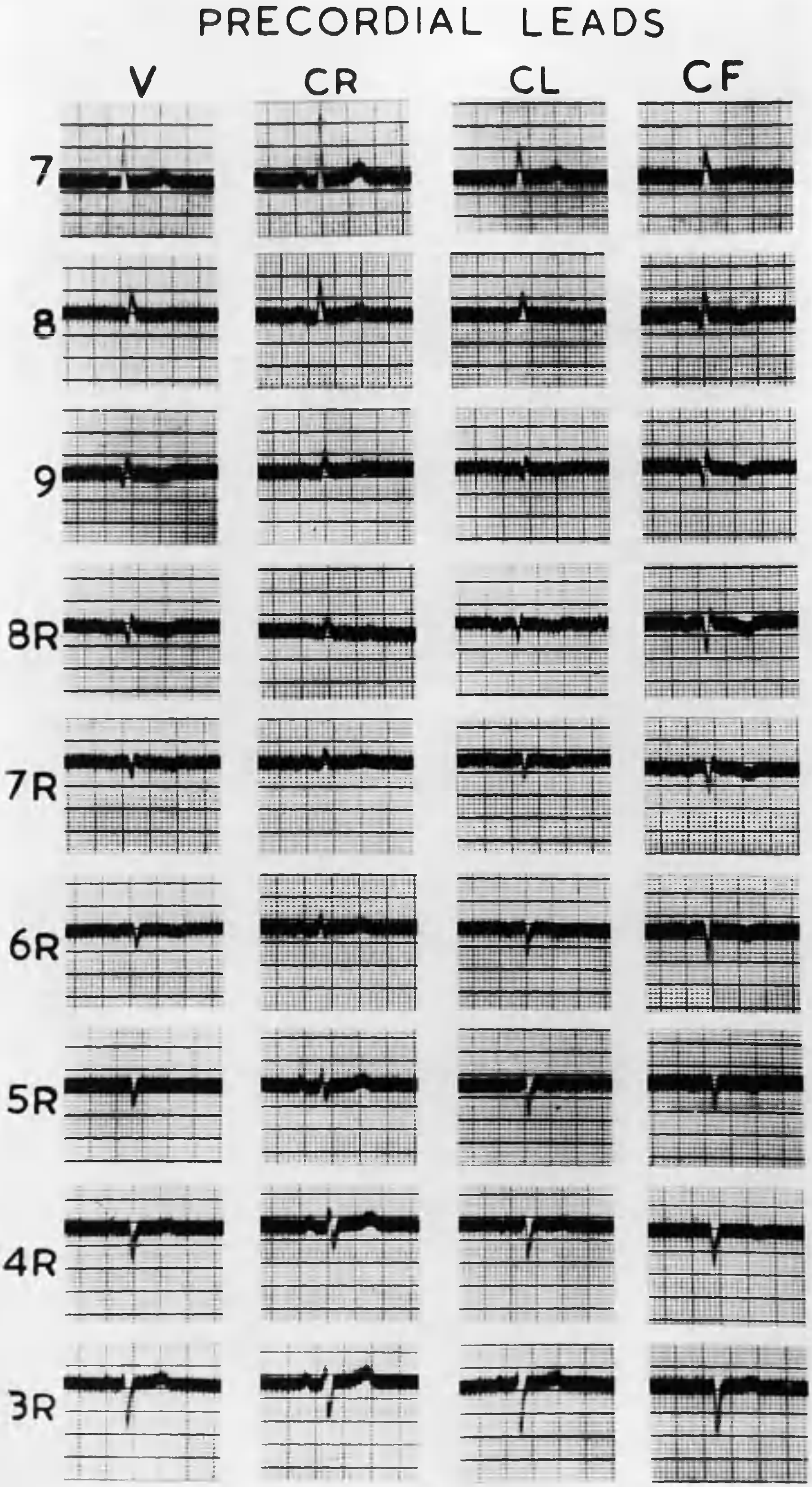
CL leads: these resemble the V leads closely.

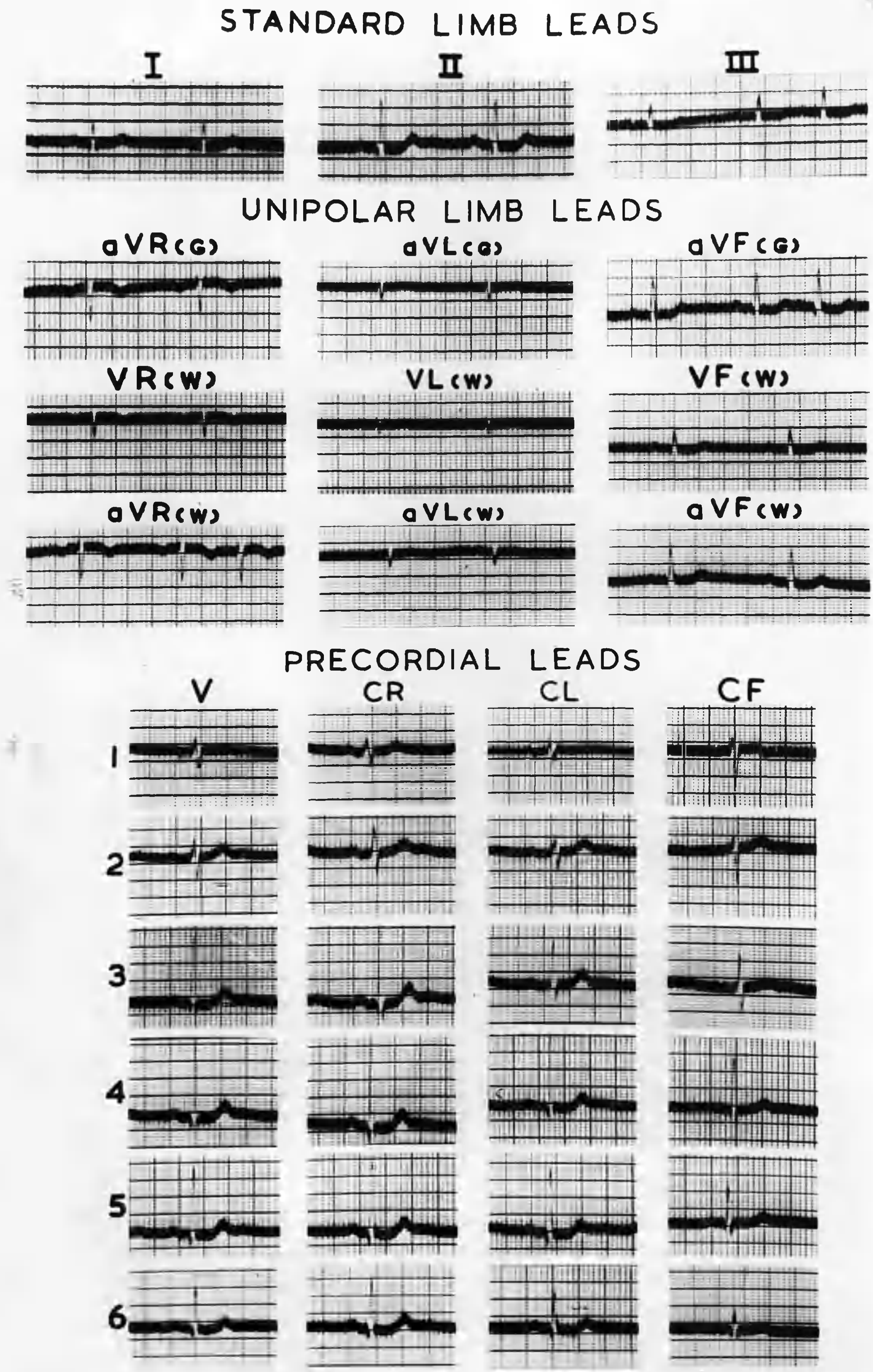
CF leads: T is positive in positions 7 and 3R and negative in all the other positions.

V leads: T is intermediate between CR and CF being positive in positions 7, 4R and 3R, flat in positions 8 and 5R and negative in the other positions.

A noteworthy feature is the complete absence of a Q wave in the CR leads. This is due to the initial Q in VR.

In position 6R the CF lead is almost an exact inversion of the CR lead.


PRECORDIAL LEADS
V
CR
CL
CF
7
8
9
8R
7R
6R
5R
4R
3R


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

ABNORMAL G.T.

Diagnosis: Chronic Cholecystitis. Age 52 years

STANDARD LIMB LEADS.

These show no axis deviation. There is slight S-T depression in leads II and III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern. There is slight S-T elevation.

The VL leads have low upright P and T waves and an rS pattern. There is no S-T deviation.

The VF leads have upright P and T waves and a qR pattern. There is slight depression of S-T.

Electrically the heart is vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

S-T interval: this is most positive in the CF leads, least positive in the CR leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 5 and 6.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from qR to R to rs.

CL leads: these show progression from qR to qr to rSR' to rsr' to rSr'.

CF leads: these show progression from qrs to qs to QS to rS.

V leads: these show progression intermediate between the extremes of the other leads, from qR to qr to rsr' to rs.

Comparison of T wave patterns.

CR leads: T remains positive throughout.

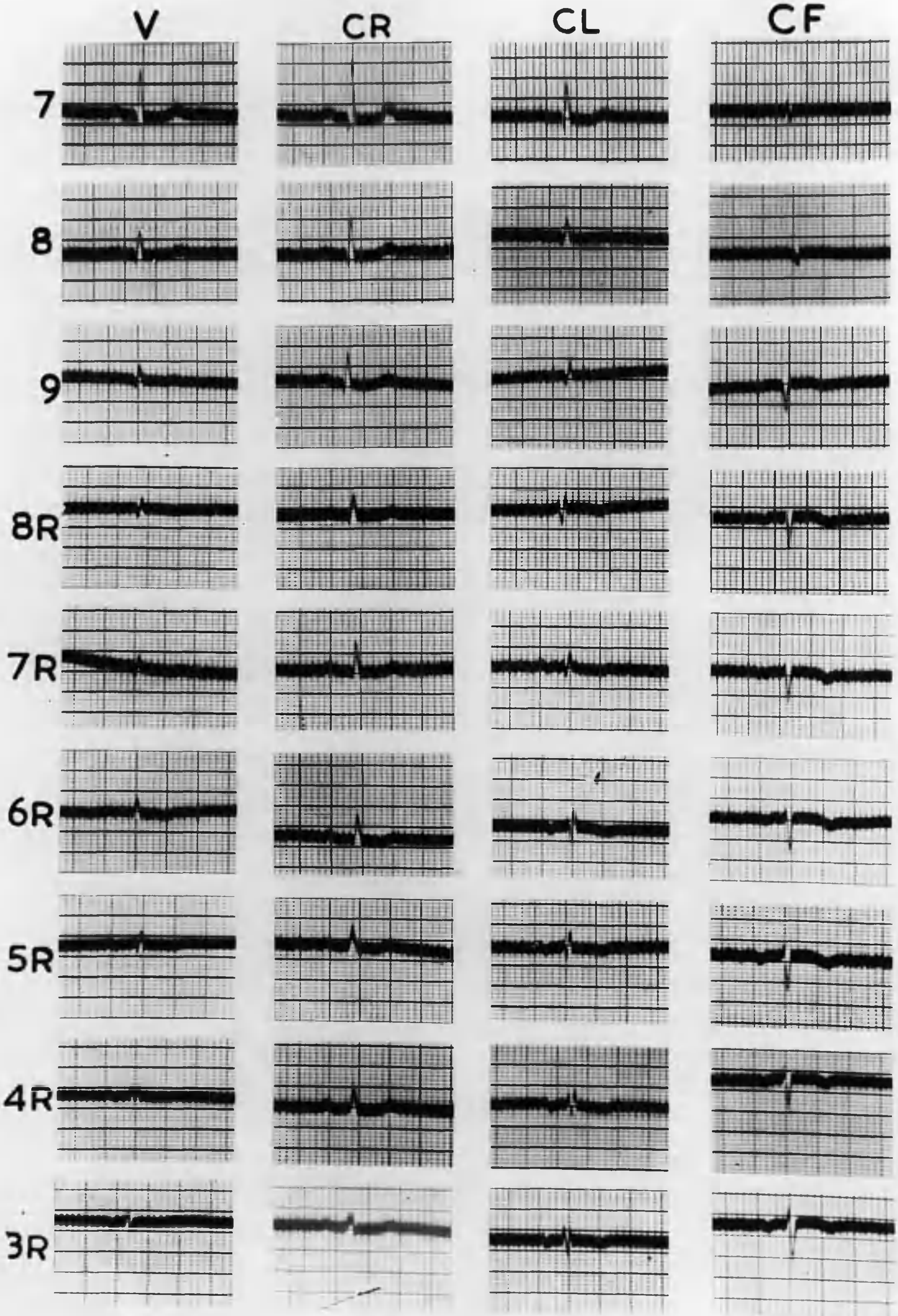
CL leads: these resemble the V leads fairly closely but are slightly less positive.

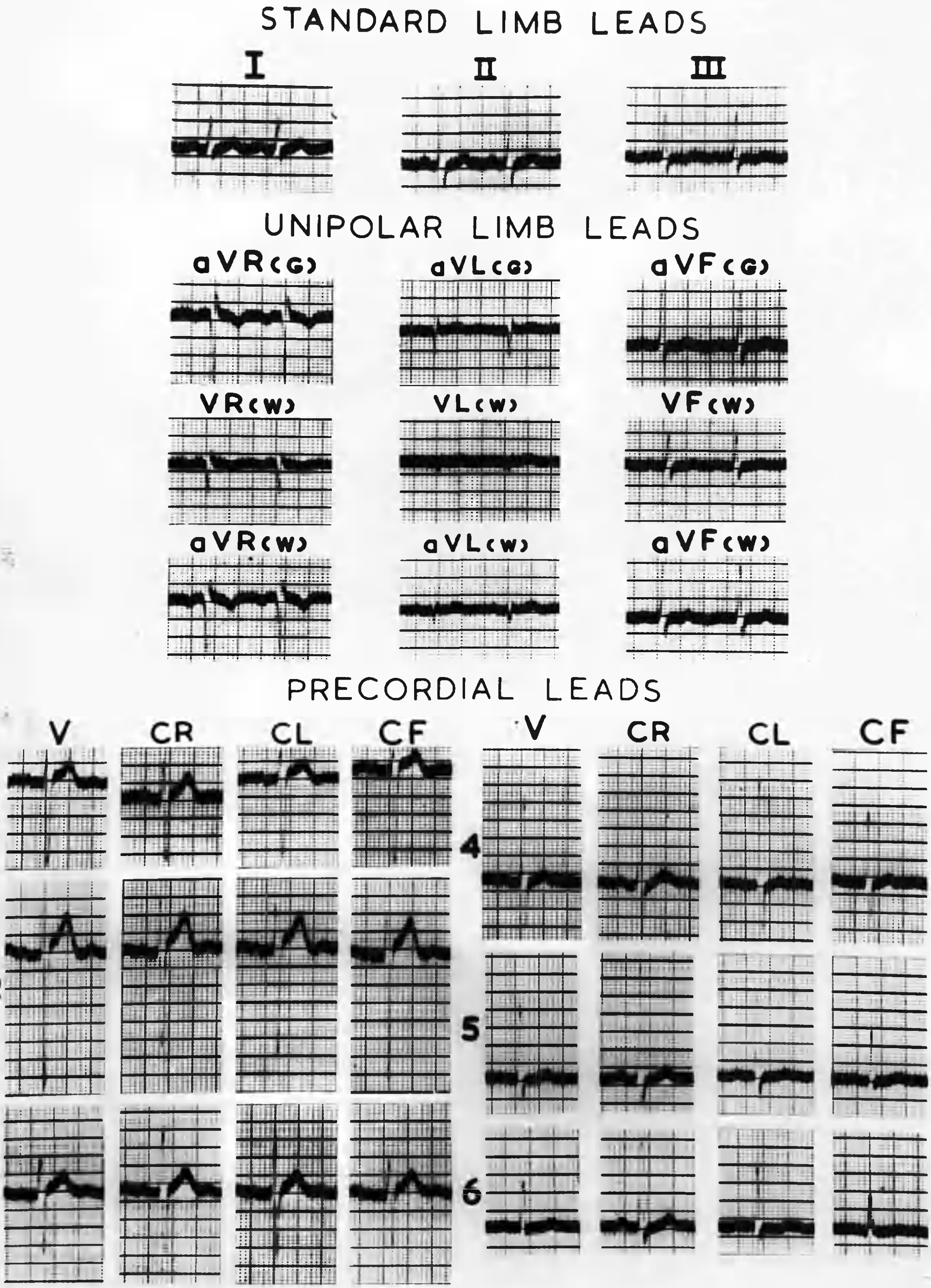
CF leads: T is flat in positions 7 and 8 and negative in all other positions.

V leads: T is intermediate between the extremes of CR and CF, being upright in positions 7 to 9, slightly negative in positions 8R to 5R and flat in positions 4R and 3R.

In position 7R the CF lead is almost an exact inversion of the CR lead.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
V
CR
CL
CF
4
5
6

CASE NO. 5 PLATE 82a

ABNORMAL. J.A.

Diagnosis: Rheumatic Heart Disease: Mitral Stenosis and Aortic Incompetence. Age I4 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and a Qr pattern.

The VL leads have upright P and T waves and an rsr' pattern.

The VF leads have upright P and T waves and an Rs pattern.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S wave in leads over the left precordium is most prominent in CR and least prominent in CF due to the r' in VR and the s in VF respectively.

T wave: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from an Rs to an RS pattern.

CL leads: these resemble the V leads fairly closely.

CF leads: these show progression from a qR to QR to Qr to QS to rS.

V leads: these show progression intermediate between the extremes of the CR and CF leads, from R to qR to QR to qr to qs to rS.

Comparison of T wave patterns.

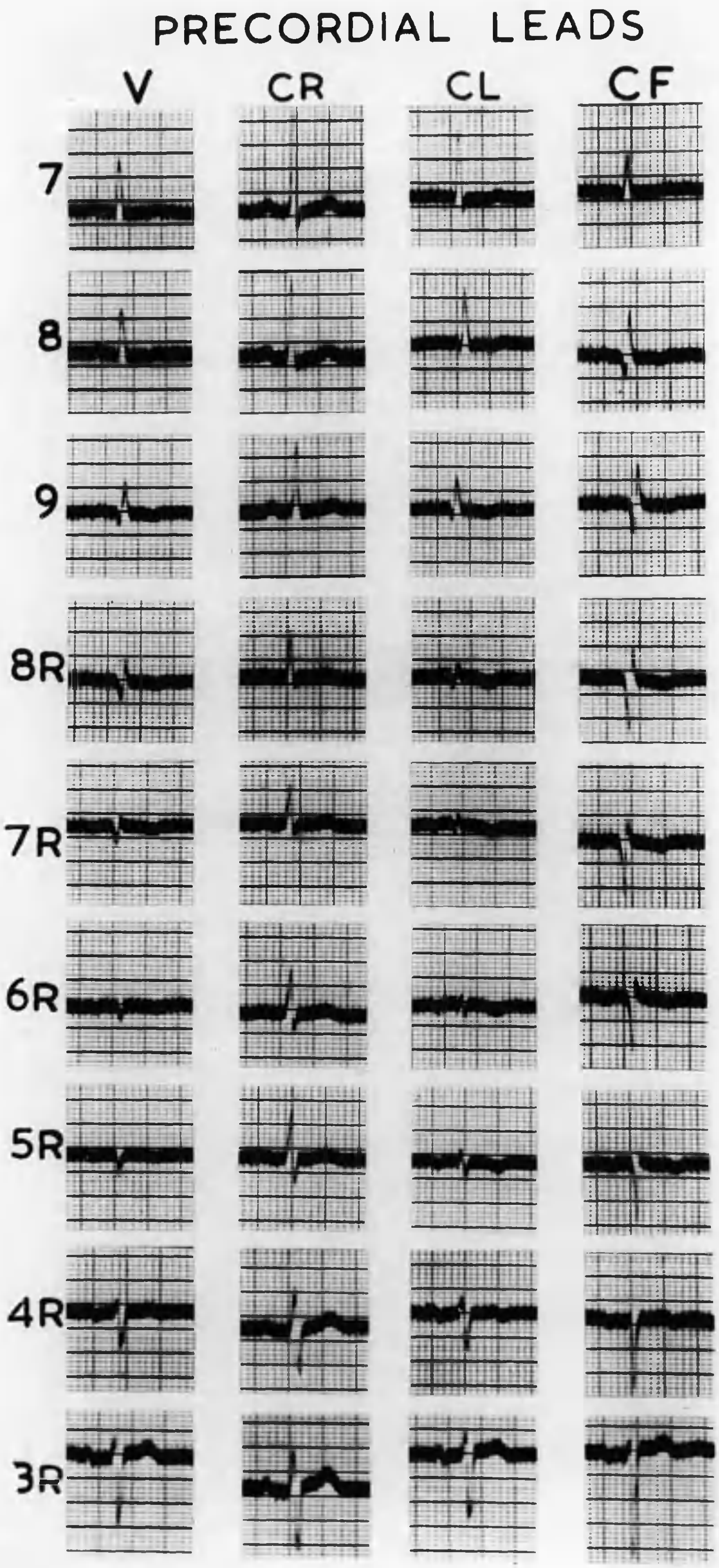
CR leads: T remains positive throughout.

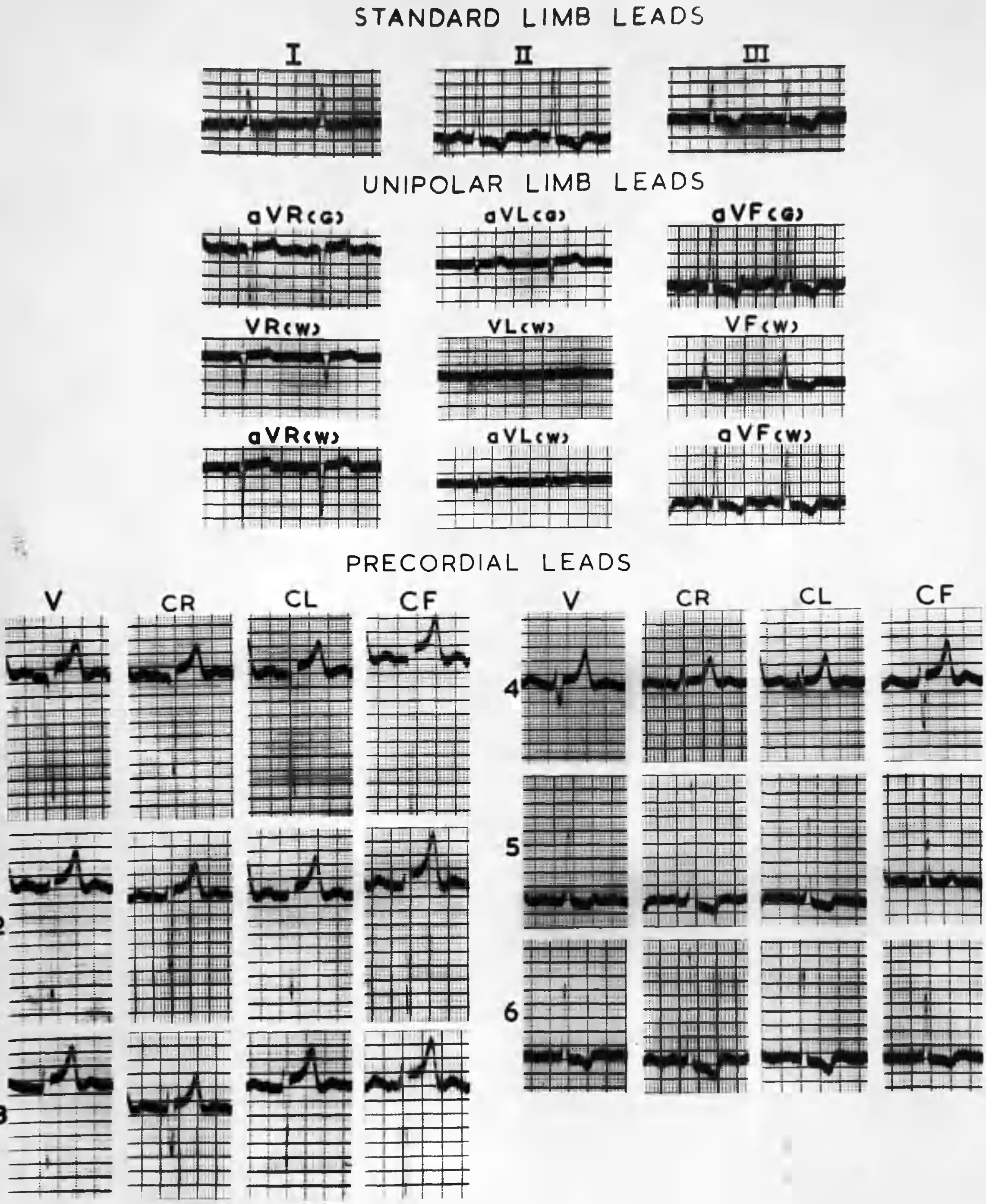
CL and CF leads: T is negative in positions 8 to 5R.

V leads: T is slightly negative in positions 8 to 5R.

One of the most noteworthy features is the complete absence of a Q wave in the CR leads. This is due to the initial Q in VR.

In position 6R the CF lead is almost an exact inversion of the CR lead.


PRECORDIAL LEADS
V
CR
CL
CF
7
8
9
8R
7R
6R
5R
4R
3R


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

ABNORMAL. G.F.

Diagnosis: Rheumatic Heart Disease: Mitral Stenosis and Aortic Incompetence.

Age 4I years.

STANDARD LIMB LEADS.

These show the appearances of right and left ventricular strain.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and upright T waves and a QS pattern. There is slight S-T elevation.

The VL leads have practically flat P and low upright T waves and a small vibratory rsr' pattern.

The VF leads have upright P and inverted T waves and a qR pattern. There is slight S-T depression.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CF leads, least positive in the CR leads and intermediate in the CL and V leads.

S-T segment: this is most positive in the CF leads, least positive in the CR leads and intermediate in the CL and V leads.

These differences are most obvious in positions 4 and 5 where the pattern of the ventricular complex is changing.

PLATE 83b

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions 1 to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from R to r(splintered) to rS to qrS.

CL leads: these show progression from qR to qR(splintered) to qrsr's' to qrS(splintered) to qrS to QS(splintered).

CF leads: these show progression from qR to Qr to QS.

V leads: these show progression intermediate between the extremes of the other leads from R to qR to QS to QS(splintered).

Comparison of T wave patterns.

CR leads: T is negative in positions 7 to 6R, flat in 5R and positive in 4R and 3R.

CL leads: T is negative in positions 7 to 7R, flat in 6R and positive in 5R to 3R.

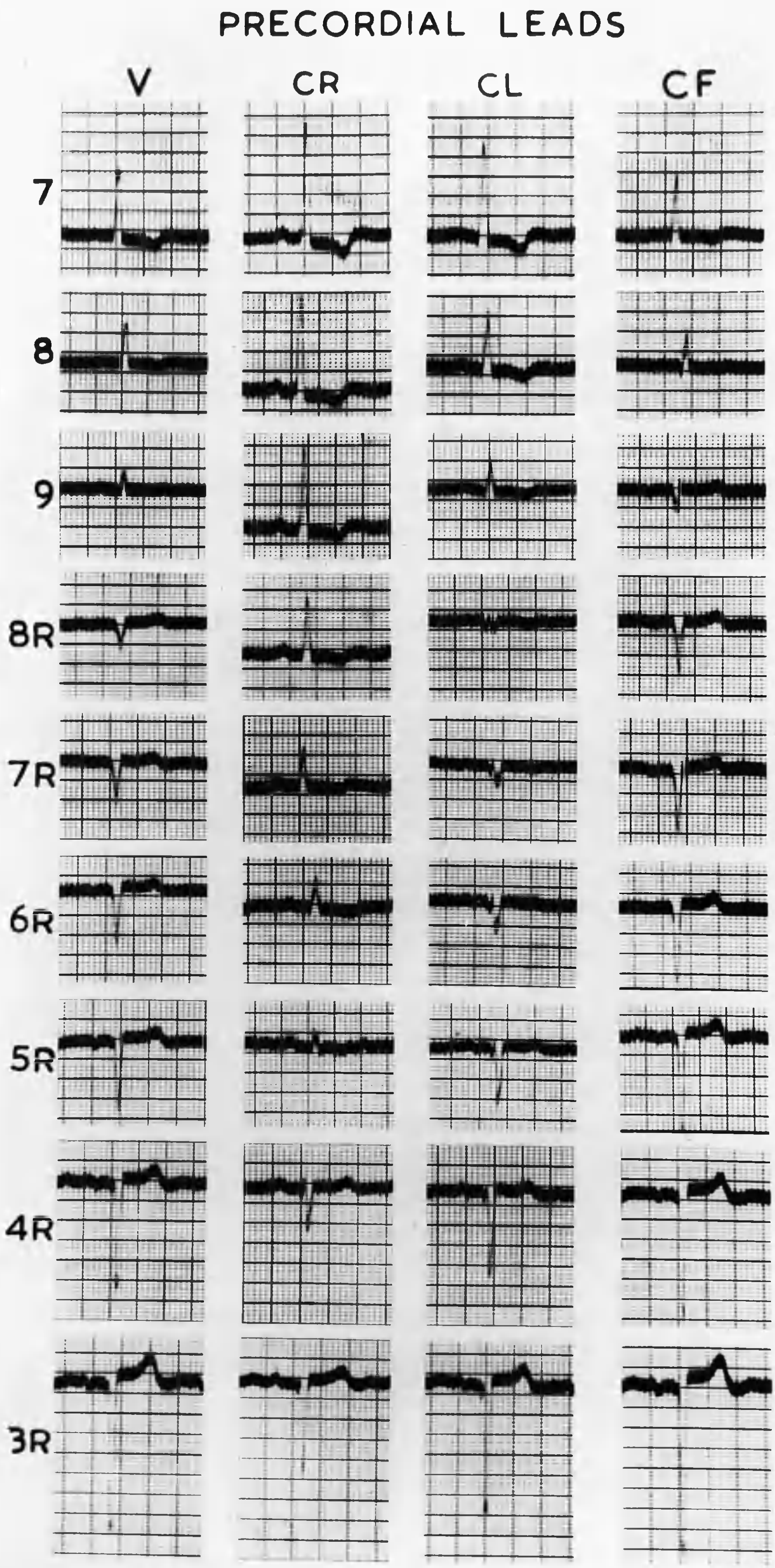
CF leads: T is negative in position 7, flat in position 8 and positive in all other positions.

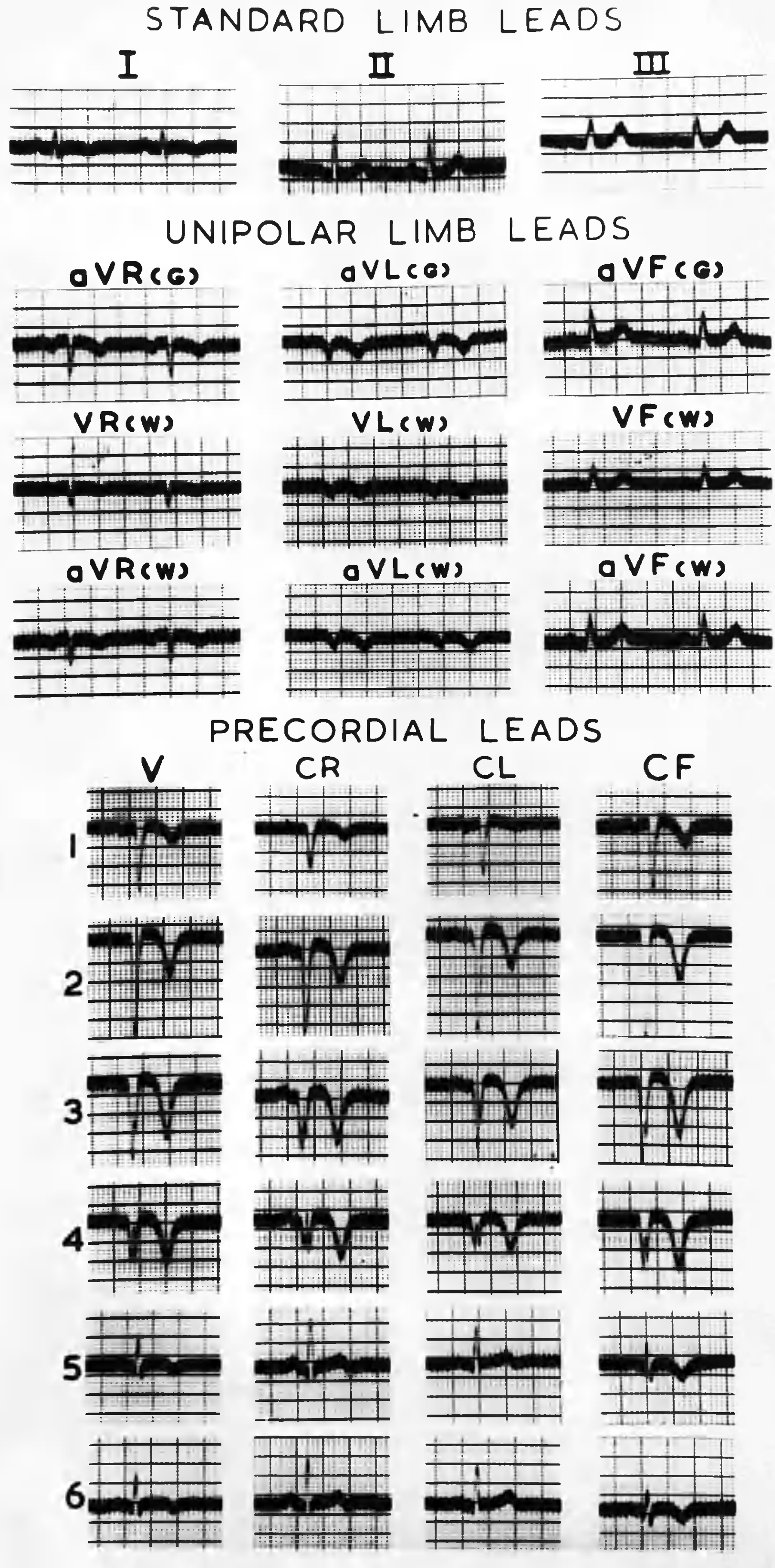
V leads: T is intermediate between the extremes of the other leads, being negative in positions 7 and 8, flat in position 9 and positive in all other positions.

Comparison of S-T patterns.

Depression of S-T ceases at position 5R in the CR leads, at position 8R in the CL leads, at position 7 in the CF leads and at position 9 in the V leads.

Elevation of S-T commences at position 3R in the CR leads, at 5R in the CL leads, at position 9 in the CF leads and at position 7R in the V leads.


PRECORDIAL LEADS
V
CR
CL
CF
7
8
9
8R
7R
6R
5R
4R
3R


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 7 PLATE 84a

ABNORMAL. J.Y.

Diagnosis: Myocardial Infarction (anterior) Age 51 years

STANDARD LIMB LEADS.

These show the appearances of anterior infarction. There is no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rS pattern.

The VL leads have practically flat P and deeply inverted T waves and a splintered qs pattern.

The VF leads have upright P and T waves and an R pattern.

Electrically the heart is semi-vertical.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

T wave: this is most positive in the CL leads, least positive in the CF leads and intermediate in the CR and V leads.

These differences are most obvious in positions 1, 5 and 6 at the edges of the infarct, where the T waves are changing in direction.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from qR to R to r to qs to QS.

CL leads: these show progression from qR to R to r to rsr' to rSr' to QS.

CF leads: these show progression from qRs to r to qs to QS.

V leads: these show progression intermediate between the extremes of the other leads from qR to r to rsr' to rS to QS.

Comparison of T wave patterns.

CR leads: T is positive in all positions except 3R where it is slightly negative.

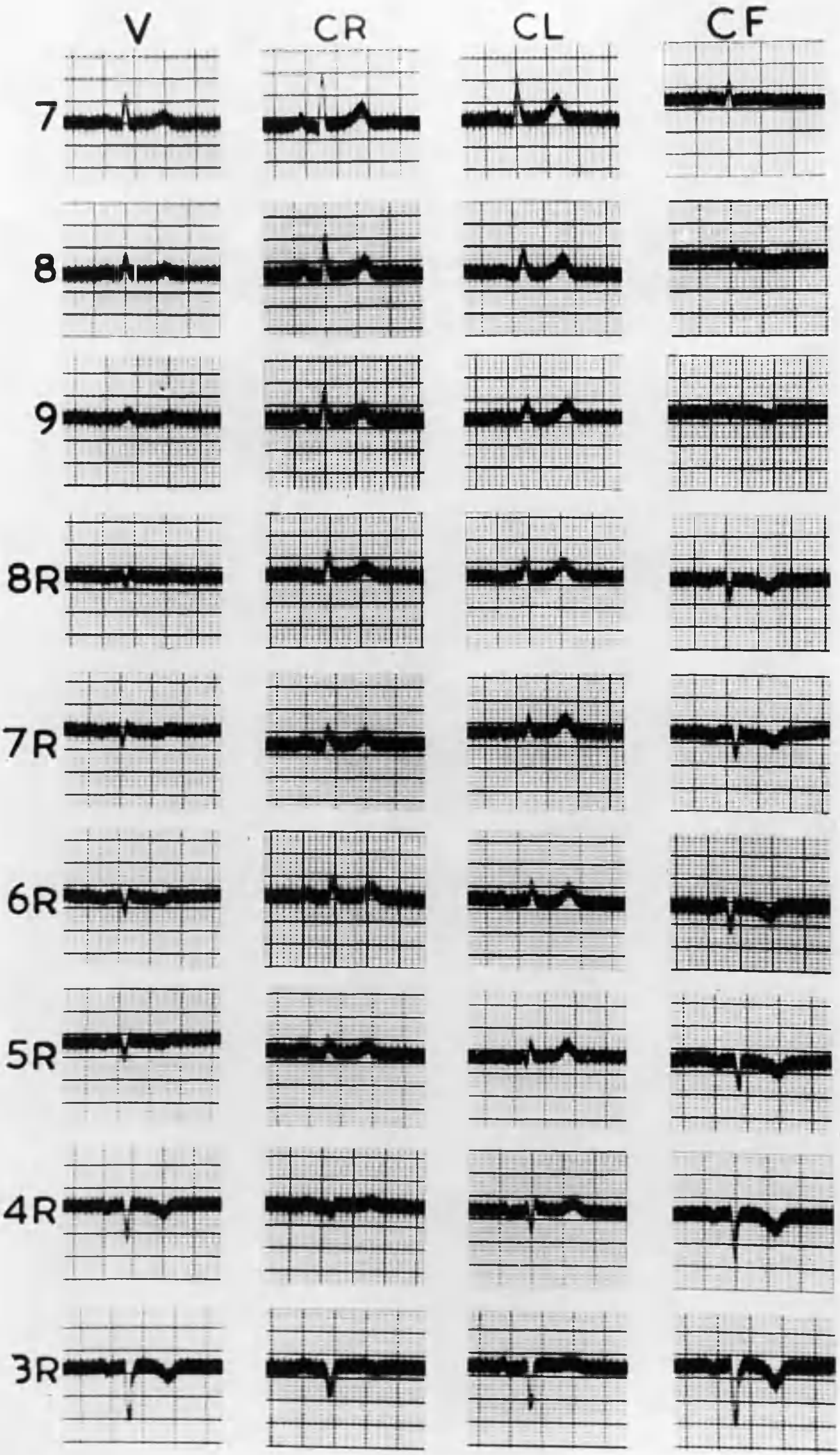
CL leads: T remains positive throughout.

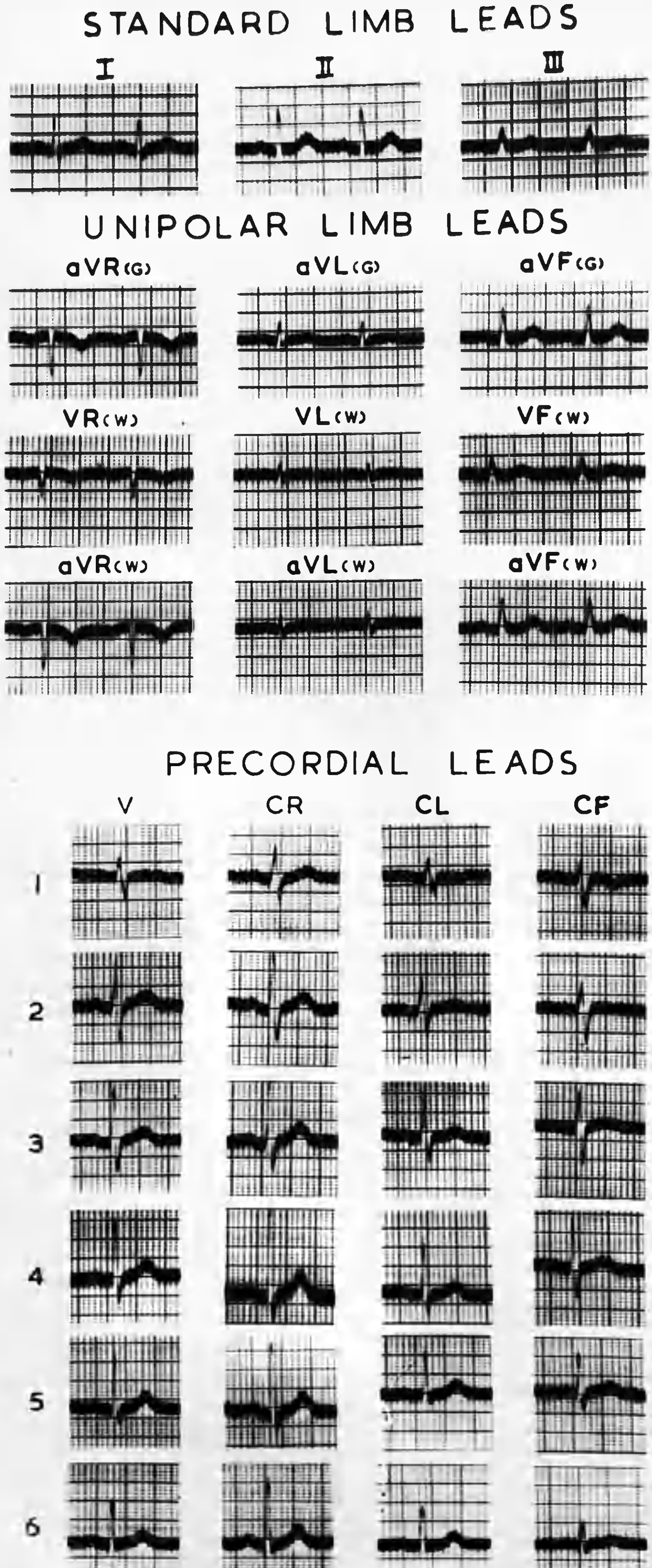
CF leads: T is flat in position 7 and negative in all the other positions.

V leads: T is intermediate between the other leads being positive in positions 7 to 9, flat in position 8R and negative in all the other positions.

In position 8R the CF lead is almost an exact inversion of the CR lead.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. 8 PLATE 85a

ABNORMAL. J.P.

Diagnosis: Chronic Coronary Artery Disease.

Age 48 years.

STANDARD LIMB LEADS.

These show no axis deviation.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rSr' pattern.

The VL leads have practically flat P and T waves and a qRs pattern.

The VF leads have upright P and T waves and an R pattern.

Electrically the heart is in the intermediate position.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads. The S is least prominent in the CL leads due to the s in VL.

T wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

These differences are most obvious in positions I, 2 and 6.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from qRs to qR to qr to r to rs to Rs.

CL leads: these resemble the V leads fairly closely.

CF leads: these show progression from qrs to qr to Qr to rSr' to rS.

V leads: these show progression intermediate between the extremes of the CR and CF leads, from qRs to qR to qr to rsr' to rs.

Comparison of T wave patterns.

CR leads: T remains positive throughout.

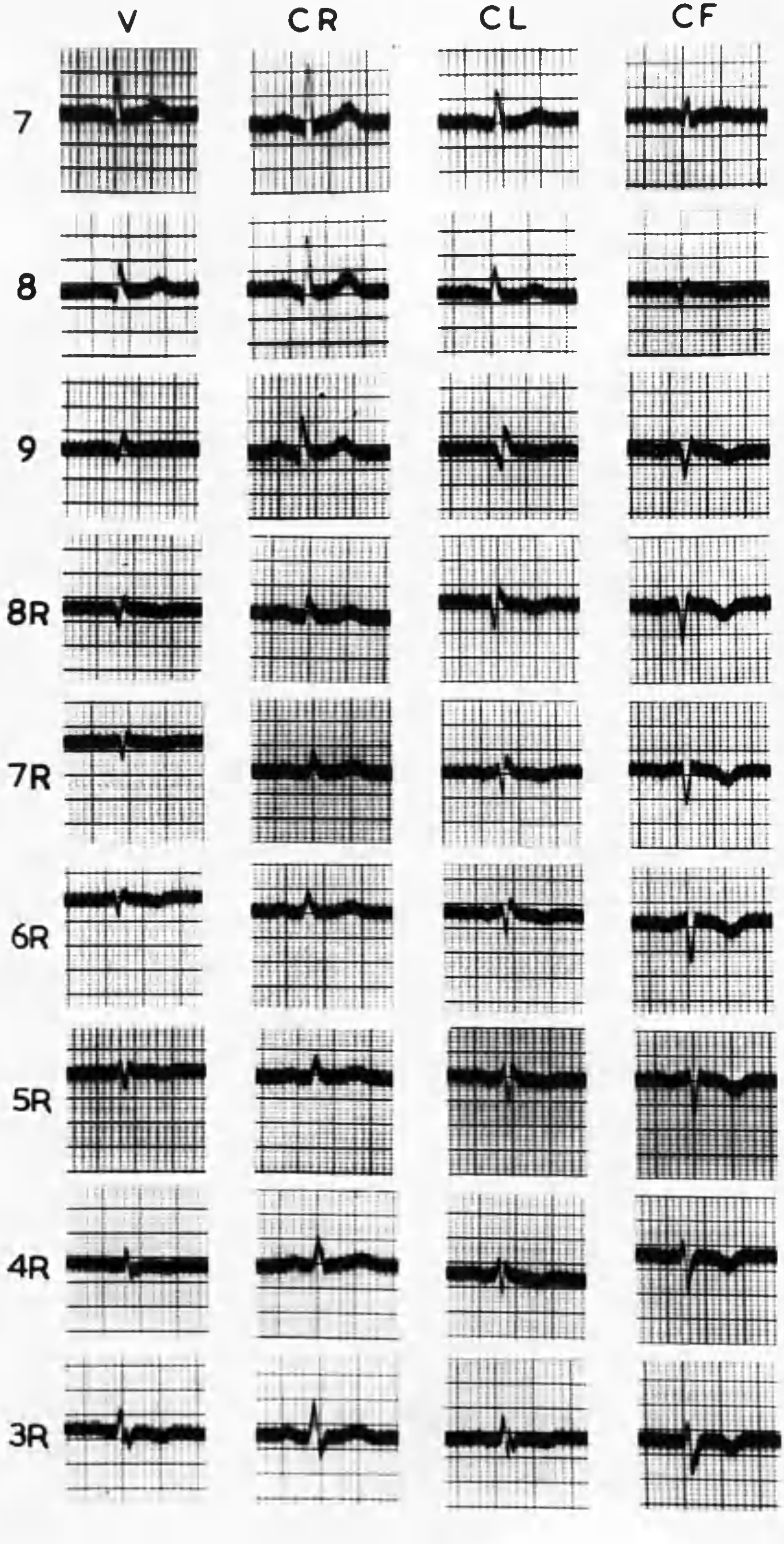
CL leads: these resemble the V leads closely but are slightly less positive.

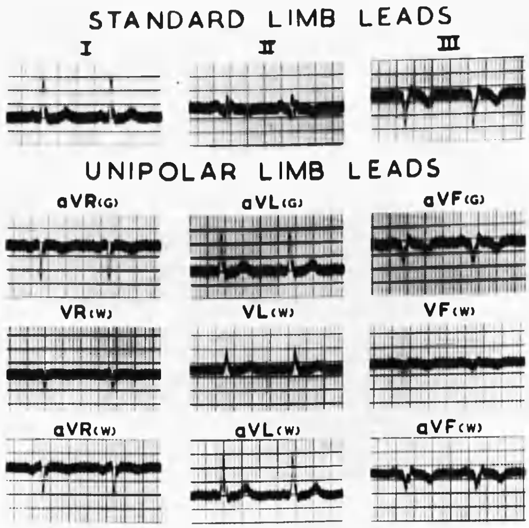
CF leads: T is flat in position 7 and negative in all the other positions.

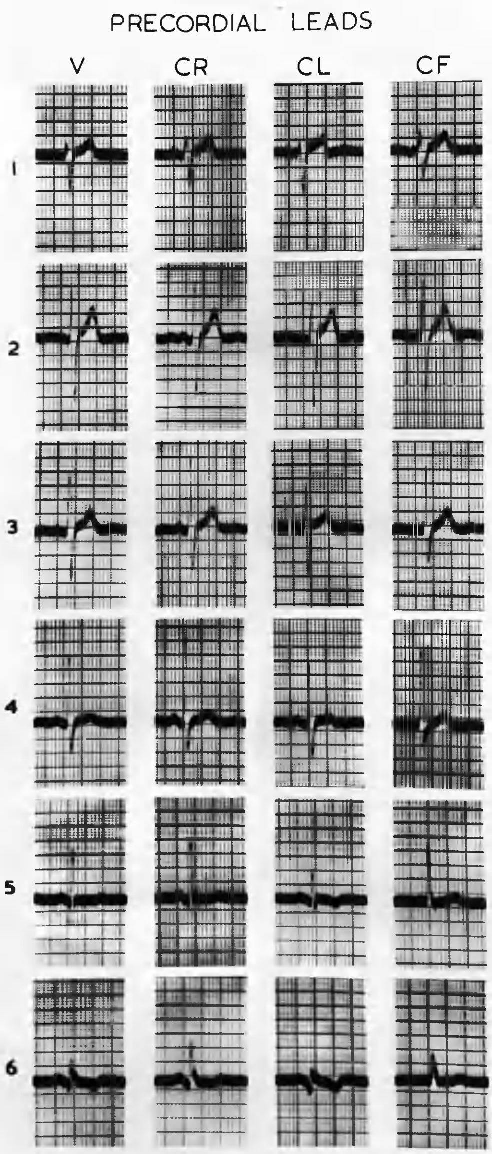
V leads: T is intermediate between CR and CF being positive in positions 7 and 8, flat in position 9 and negative in all the other positions.

A q appears in some of the CR leads. This is due to the initial r in VR.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)


PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

ABNORMAL. A.S.

Diagnosis: Myocardial Infarction (posterior) Age 54 years

STANDARD LIMB LEADS.

These show a deep Q in lead III and inverted T waves in leads II and III.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and T waves and an rS pattern.

The VL leads have practically flat P and upright T waves and an Rs pattern.

The VF leads have upright P and inverted T waves and a splintered Qr pattern.

Electrically the heart is horizontal.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL leads and intermediate in the CF and V leads.

T wave: this is most positive in the CF leads, least positive in the CL leads and intermediate in the CR and V leads.

These differences are most obvious in positions 5 and 6 where the T wave is changing from positive to negative, and where the deep Q pattern is appearing. The latter is delayed in CF due to the Q in VF. Note also the splintering of R in V6, CR6 and CL6 and its absence in CF6, due to the splintering of the Qr in VF.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from qR (notched) to qr(notched) to qrsr' to qr(notched) to qs(notched) to rS.

CL leads: these show progression from Qr to rS.

CF leads: these show progression from R to qR to Qr to qs(splintered) to rS to RS.

V leads: these show progression intermediate between the extremes of the other leads from qR(splintered) to Qr to rS.

Comparison of T wave patterns.

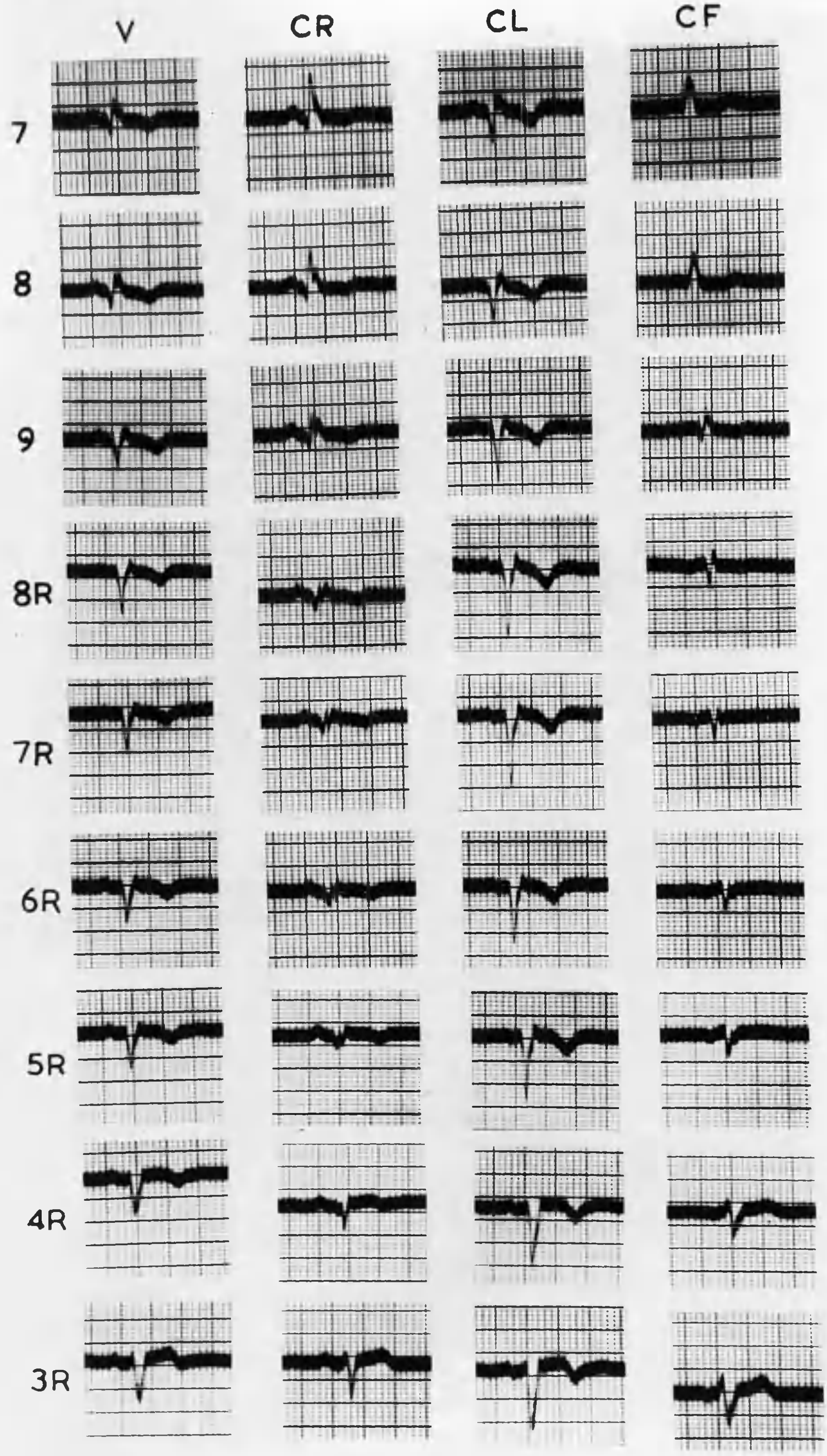
CR leads: T is diphasic in position 7, negative in positions 8 to 5R, diphasic in position 4R and upright in position 3R.

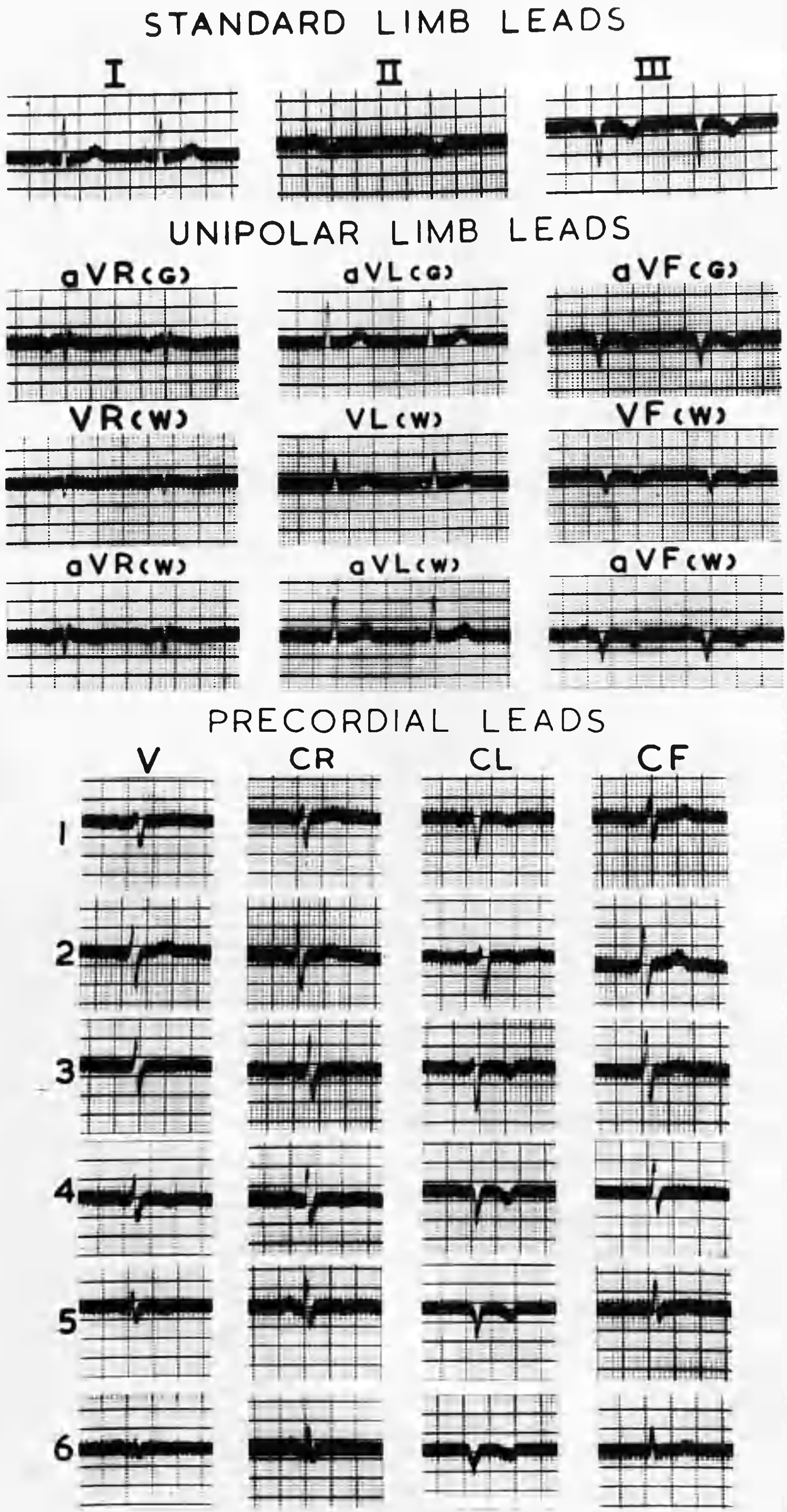
CL leads: T remains negative throughout.

CF leads: T is positive in positions 7 to 9, flat in positions 8R to 5R and positive in positions 4R and 3R.

V leads: T is intermediate between the extremes of the other leads, being negative in all positions except 3R where it is diphasic.

PRECORDIAL LEADS





STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6

CASE NO. IO PLATE 87a

ABNORMAL J.B.

Diagnosis: Myocardial Infarction: posterior. Age 5I years.

STANDARD LIMB LEADS.

These show L.A.D. and the pattern of posterior infarction.

UNIPOLAR LIMB LEADS.

The VR leads have inverted P and shallow inverted T waves and an rSr' pattern.

The VL leads have shallow diphasic P and upright T waves and an R pattern.

The VF leads have upright P and inverted T waves and a QS pattern.

Electrically the heart is horizontal.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CF and CR leads, least positive in the CL leads and intermediate in the V leads.

T wave: this is most positive in the CF leads, least positive in the CL leads and intermediate in the CR and V leads.

These differences are obvious in all positions.

PRECORDIAL LEADS from POSITIONS 7 to 3R.

The differences between the four types of lead are similar to those already described for positions I to 6. They are however more obvious due to the smaller size of the deflections and the changing patterns encountered.

Comparison of QRS patterns.

CR leads: these show progression from qRs to qrs to qs to QS.

CL leads: these show progression from QS to Qr to QS to rS.

CF leads: these show progression from R to r to rsr' to rs.

V leads: these show progression intermediate between the extremes of the other leads from qrs to qr to Qr to QS.

Comparison of T wave patterns.

CR leads: these resemble the V leads fairly closely but are slightly more positive.

CL leads: T remains negative throughout.

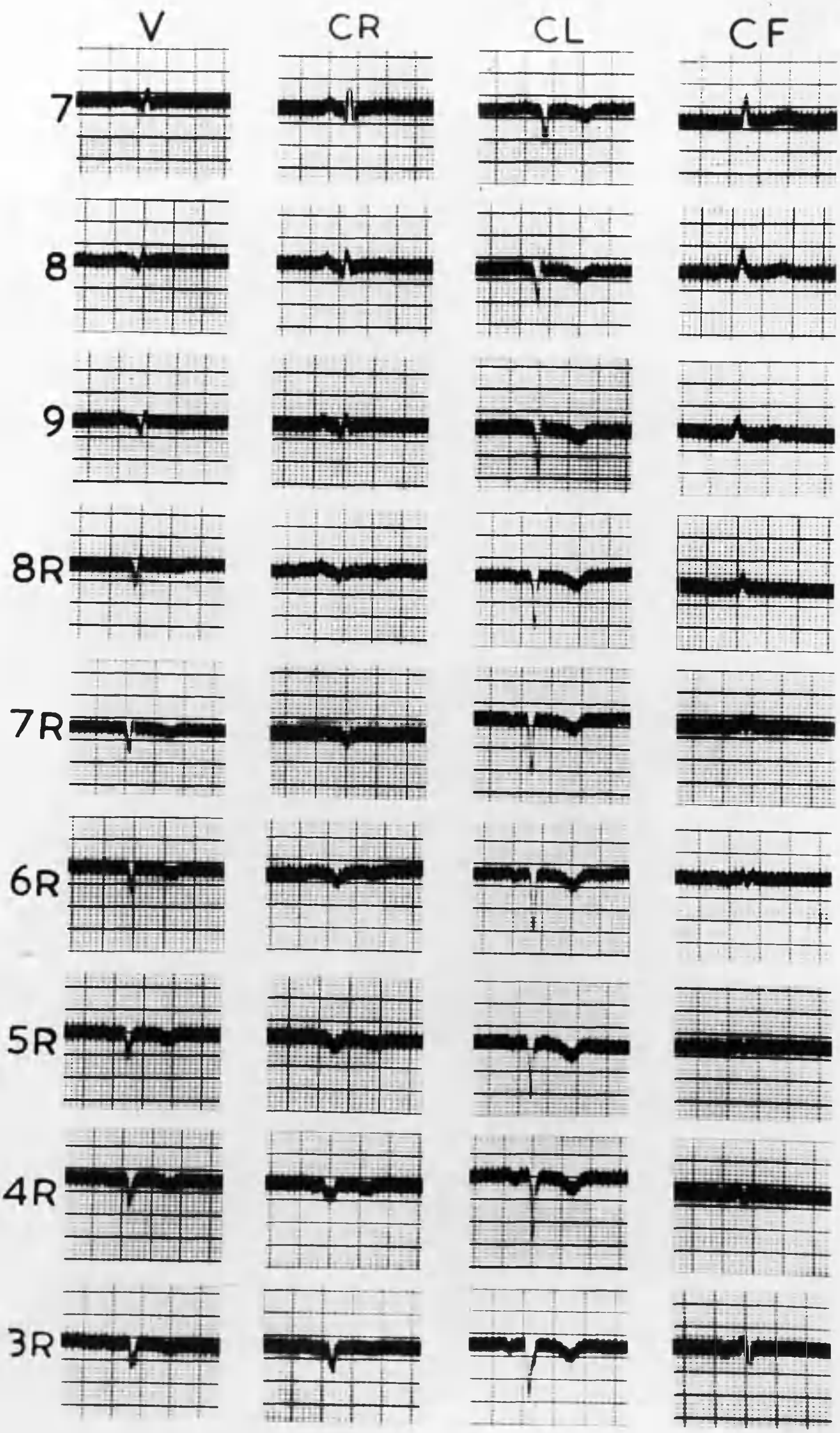
CF leads: T is positive in positions 7 to 9 and flat in all the other positions.

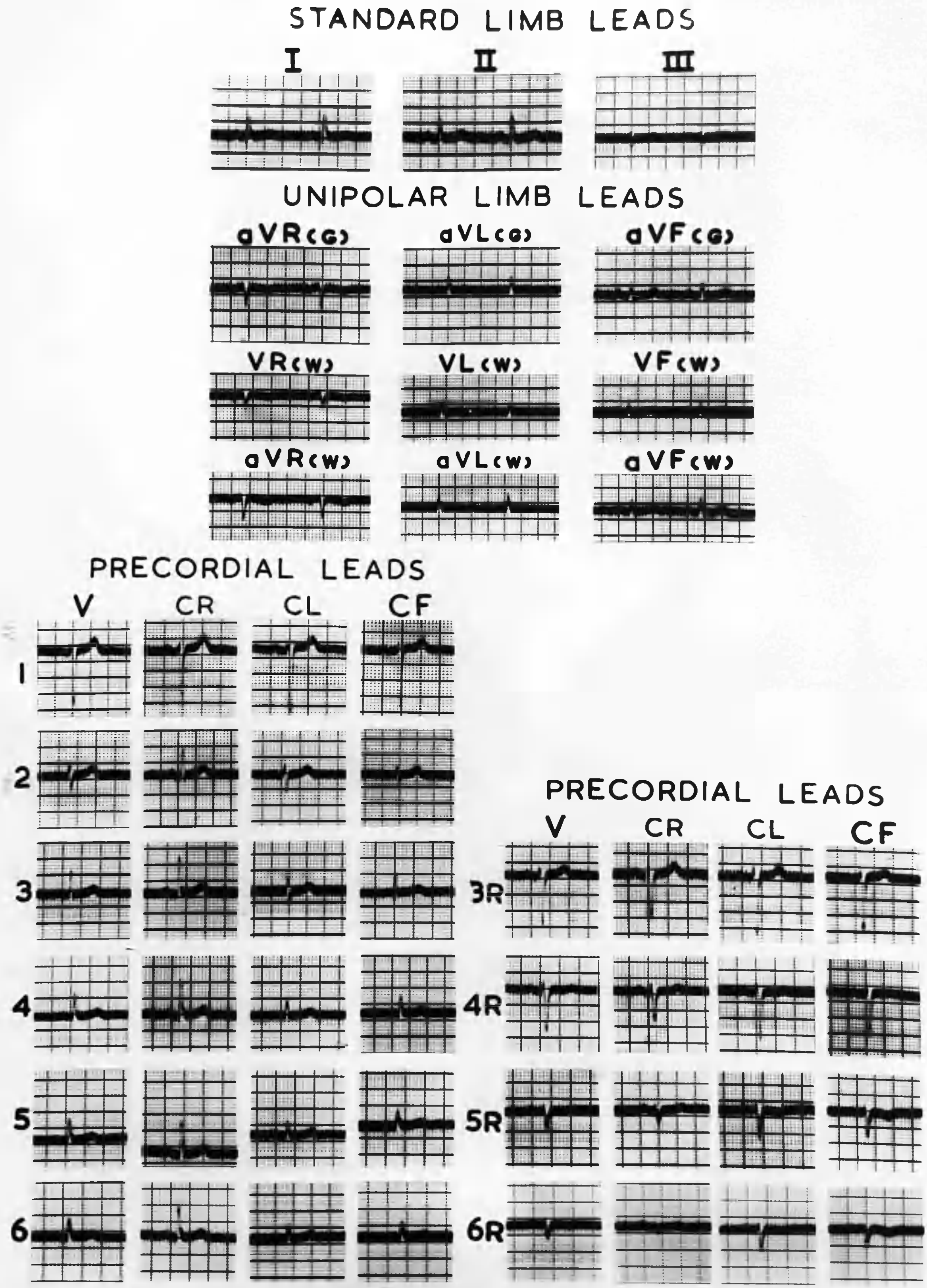
V leads: T is intermediate between CL and CF being flat in positions 7 and 8 and slightly negative in all the other positions.

A noteworthy feature is the complete absence of a Q wave in the CF leads. This is due to the QS pattern in VF.

In position 7R the CF lead is almost an exact inversion of the CR lead.
In position 7 the CL lead is almost an exact inversion of the CF lead.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
aVR(W)
aVL(W)
aVF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6
PRECORDIAL LEADS
V
CR
CL
CF
3R
4R
5R
6R

ABNORMAL. G.McM.

Diagnosis: Pleurisy with Effusion: (left) Age 54 years.

Tracings before Paracentesis.

STANDARD LIMB LEADS.
These show slight tendency to L.A.D.

UNIPOLAR LIMB LEADS.
The VR leads have inverted P and flat T waves and an rS pattern.

The VL leads have flat P and T waves and an R pattern.

The VF leads have upright P and flat T waves and an R pattern.

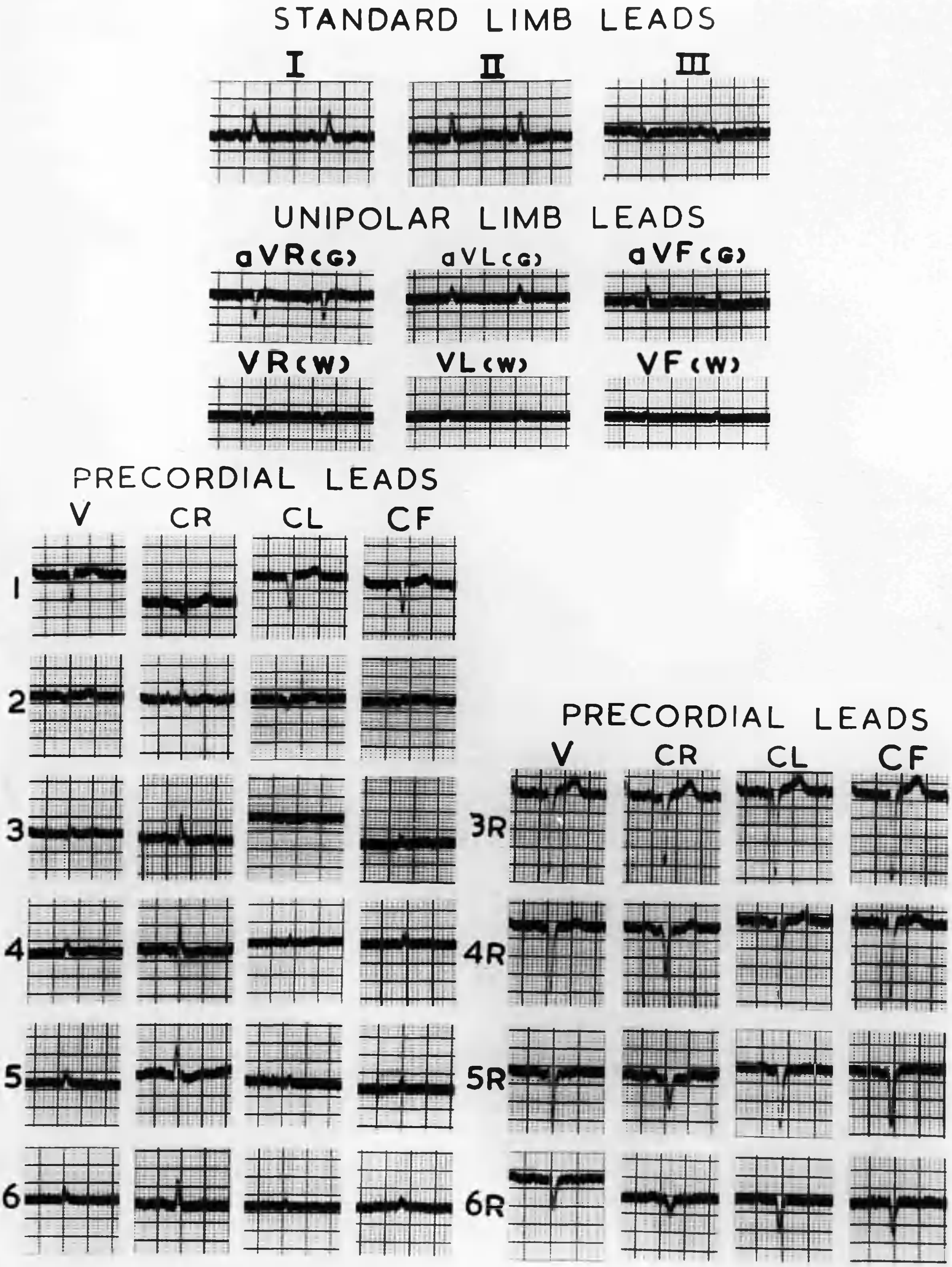
Electrically the heart is in the intermediate position.

PRECORDIAL LEADS.

P wave: this is most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

QRS complex: this is most positive in the CR leads, least positive in the CL and CF leads and intermediate in the V leads.

T wave: there are no obvious differences in the T waves in the V,CR,CL and CF leads. This is because the T waves are flat in all three unipolar limb leads.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6
PRECORDIAL LEADS
V
CR
CL
CF
3R
4R
5R
6R

Tracings after first Paracentesis.

STANDARD LIMB LEADS.

There is a slight increase in the amplitude of the T waves in all leads.

UNIPOLAR LIMB LEADS.

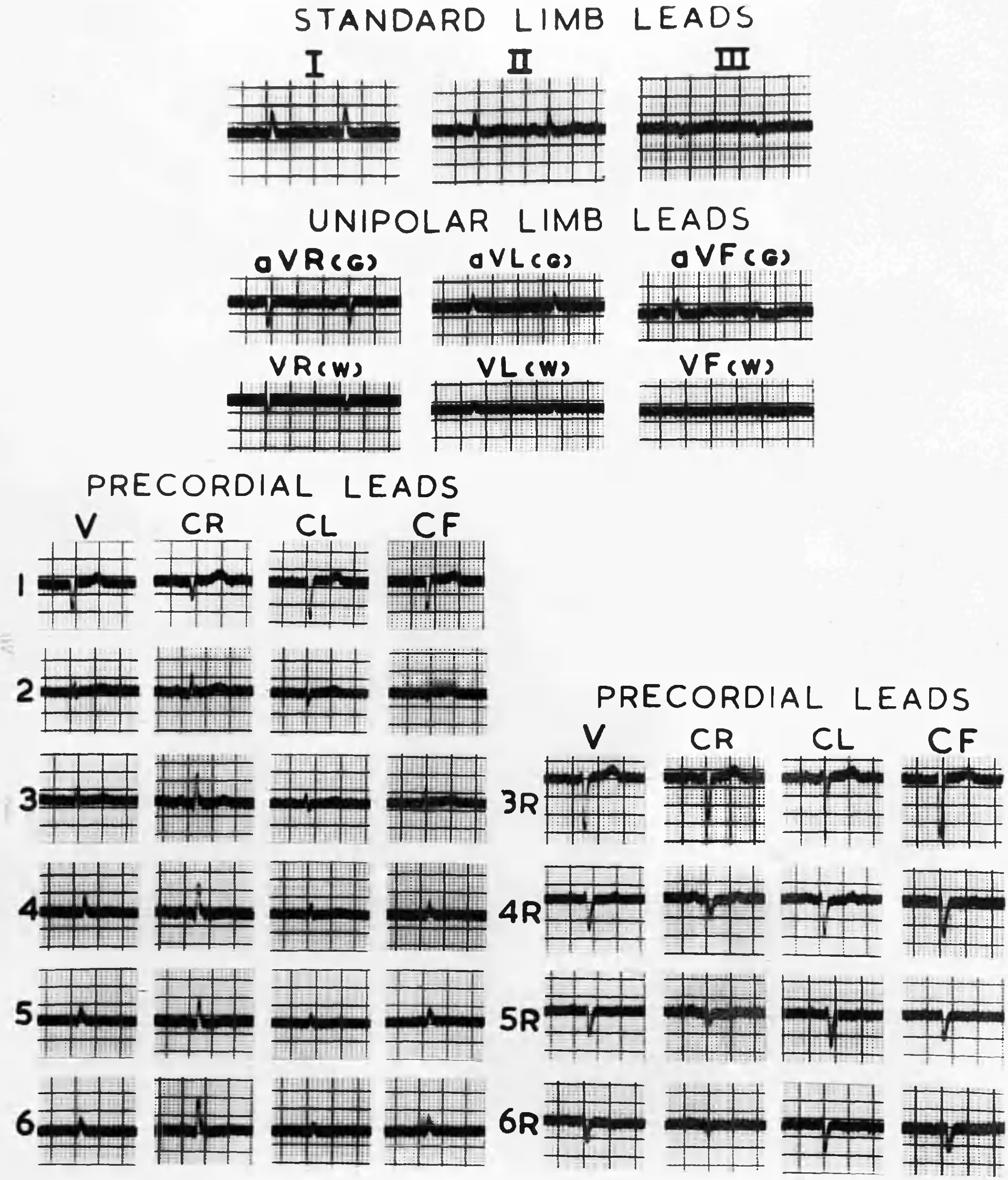
The T wave is now slightly inverted in VR and low upright in VF. It remains flat in VL.

PRECORDIAL LEADS.

There is diminution in amplitude of the QRS complex and T wave in leads over the right side of the chest.

There is an increase in amplitude of the QRS complex and T wave in leads over the left side of the chest.

The differences between the V,CR,CL and CF leads are present as before.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
PRECORDIAL LEADS
V
CR
CL
CF
1
2
3
4
5
6
PRECORDIAL LEADS
V
CR
CL
CF
3R
4R
5R
6R

Tracings after second Paracentesis.

STANDARD LIMB LEADS.

There is a further increase in the amplitude of the T waves in all leads.

UNIPOLAR LIMB LEADS.

There is a further increase in the amplitude of the T waves in leads VR and VF. The T wave is now definitely inverted in VR and upright in VF. It remains flat in VL.

PRECORDIAL LEADS.

The leads over the right side of the chest show no difference from the previous tracings.

In leads over the left side of the chest there is a further obvious increase in the amplitude of the QRS complex and T wave.

The differences between the V,CR,CL and CF leads are present as before.

In addition differences in the T waves can now be seen. These are most positive in the CR leads, least positive in the CF leads and intermediate in the CL and V leads.

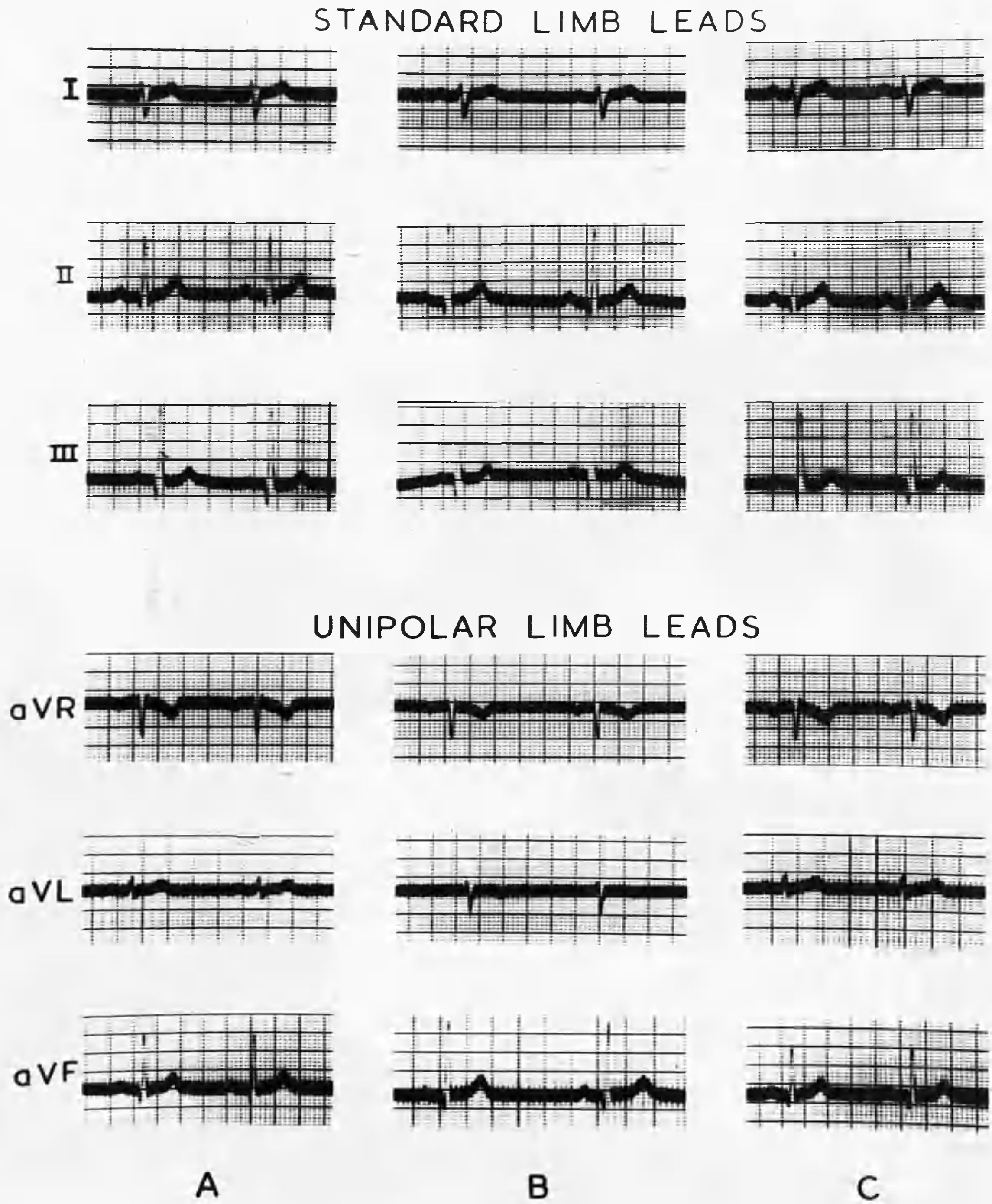
STUDIES IN ELECTROCARDIOGRAPHY

APPENDIX B

Plates 9I to I30

PART III

Plates 9I to I30.


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. I

NORMAL. P.H.

Age 29 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Lead I has an rS pattern.
Lead II has a qRs pattern.
Lead III has a qR pattern.
There is right axis deviation.

B: Inspiration.

The basic patterns are unaltered but lead I shows decrease in r; lead II shows increase in q and R and decrease in s and T; lead III shows increase in q and R.

There has been a shift in the QRS axis to the right.

C: Expiration.

The patterns are very similar to the control series but lead I shows slight decrease in S while leads II and III show decrease in R.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.

aVL has upright P and T waves and a small Rs pattern. It faces the epicardial surface of the right ventricle.

aVF has a qRs pattern and upright P and T waves. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR shows a less inverted T.

aVL has shallow inverted P and T waves and an rS pattern.

aVF still has a qRs pattern with considerable increase in R; P is also increased.

The heart has become more vertical.

C: Expiration.

Patterns are similar to those of the control series but R in aVL is taller and in aVF is smaller.

The heart has become less vertical.

PLATE 9Ib

PRECORDIAL LEADS.

A: Control.

VI to V3 have rS patterns.
V4 to V6 have qRs patterns.
P is upright in all leads.
T is slightly inverted in VI and upright in all other leads.

B: Inspiration.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qRs pattern.
T is upright in all leads; in V4 to V6 it is considerably reduced.
There has been clockwise rotation of the heart.

C: Expiration.

The patterns are identical with the control series but in V4 to V6 there is some reduction in the height of R and T.

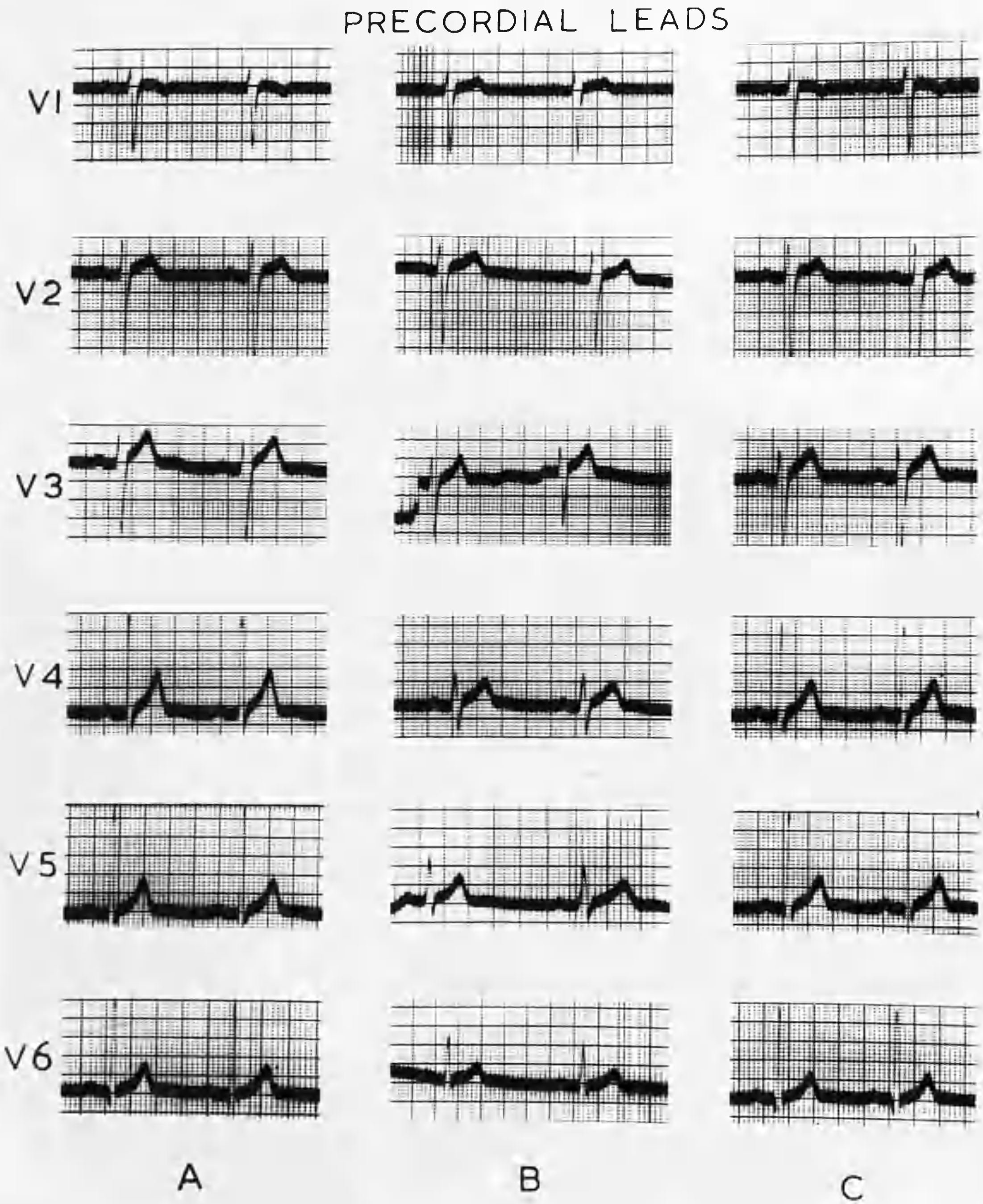
This may be due to the heart becoming less vertical so that the left ventricle moves upwards away from these leads.

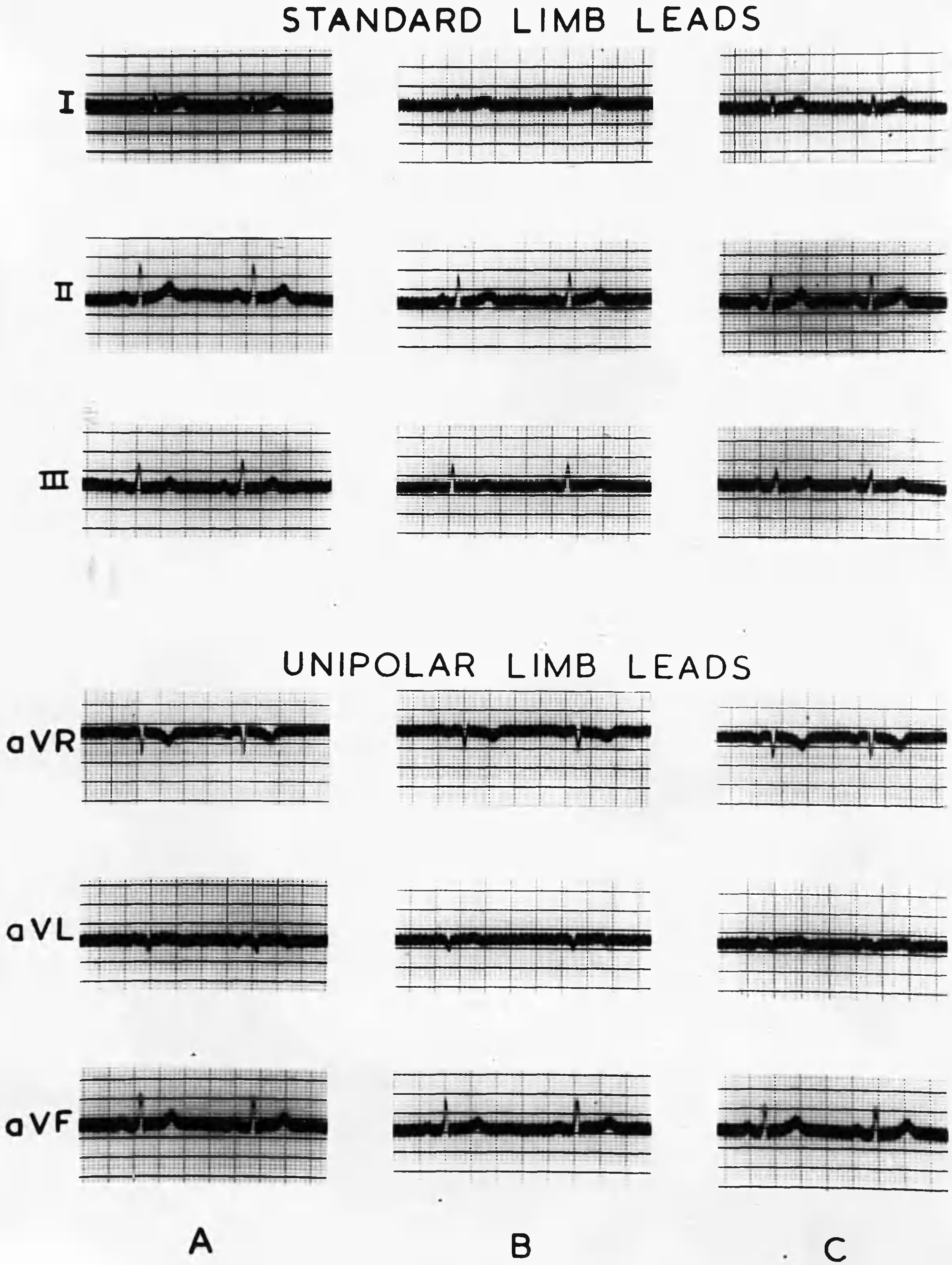
SUMMARY.

This is a normal vertical heart with moderate counter-clockwise rotation.

On inspiration the heart becomes more vertical and undergoes considerable clockwise rotation.

On expiration the reverse changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.2 PLATE 92a

NORMAL. G.McL.

Age 32 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Lead I has a small qRs pattern.
Leads II and III have Rs patterns.
There is a tendency to right axis deviation.

B: Inspiration.

Lead I shows decrease in P,R and T.
Lead II shows decrease in R and T.
Lead III shows decrease in P and T and an R pattern.
There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are identical with the control series but lead I shows an increase in R and T; lead II shows a decrease in R; lead III shows a decrease in R and T.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a Qr pattern. It tends to face the back of the heart.

aVL has inverted P and shallow diphasic T waves and a small Qr pattern. It tends to face the back of the heart.

aVF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR has less inverted P and T waves and a smaller Q.

aVL has flat P and shallow diphasic T waves and a qs pattern.

aVF has taller R.

The heart has become slightly more vertical.

C: Expiration.

aVL has a small vibratory qr pattern and low upright T waves.

aVF has slight reduction in R.

The heart has become slightly less vertical.

PLATE 92b

PRECORDIAL LEADS.

A: Control.

V1 and V2 have RS patterns.
V3 has an Rs pattern.
V4 and V5 have qRs patterns.
V6 has an Rs pattern.
P and T are upright in all leads.

B: Inspiration.

All leads are practically identical with the control series though there is slight reduction of R in V1,V2 and V3.

There has been little if any rotation of the heart.

C: Expiration.

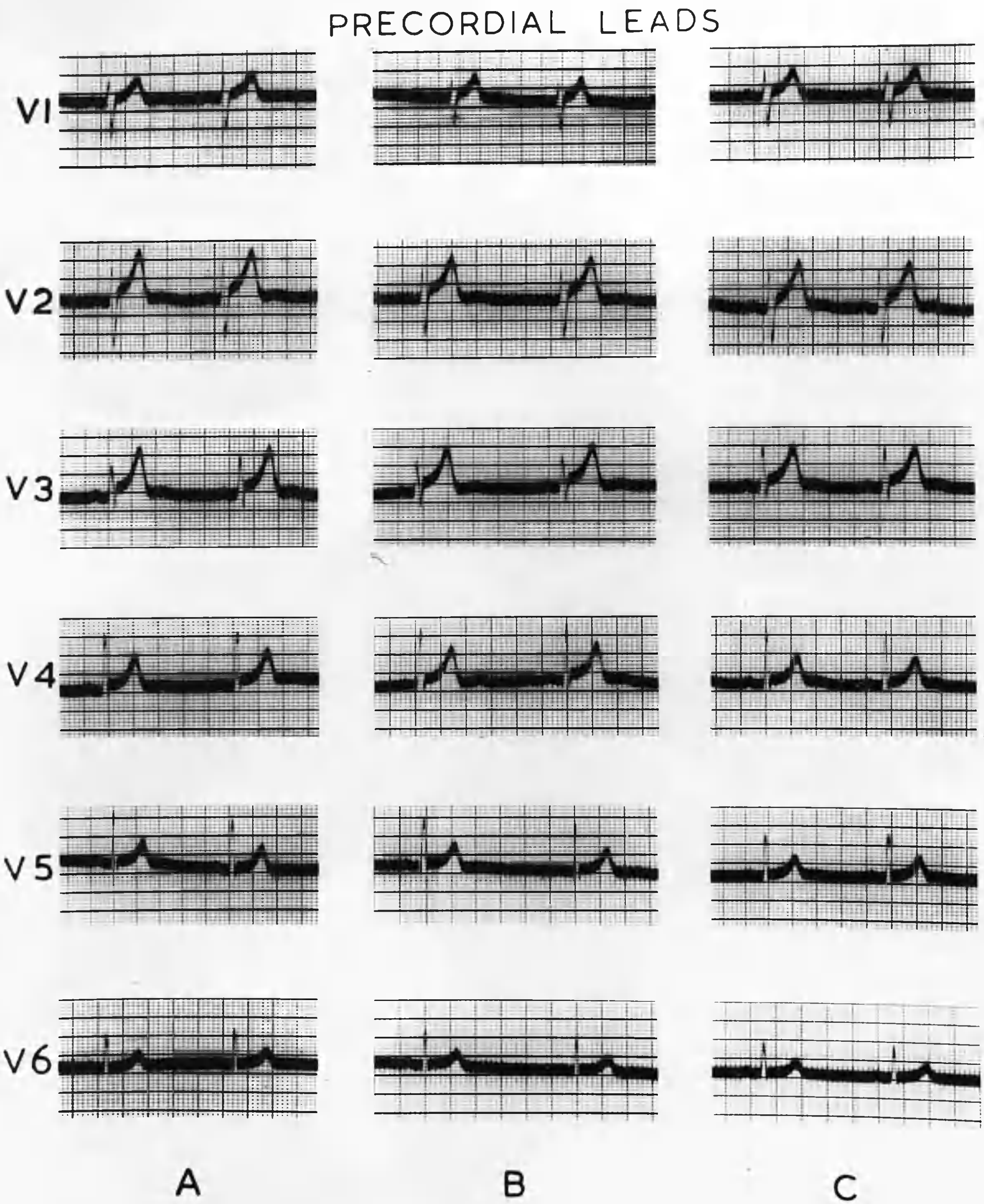
All leads are practically identical with the control series, though there is slight reduction of s in V3,V4 and V5. There has been slight counter-clockwise rotation.

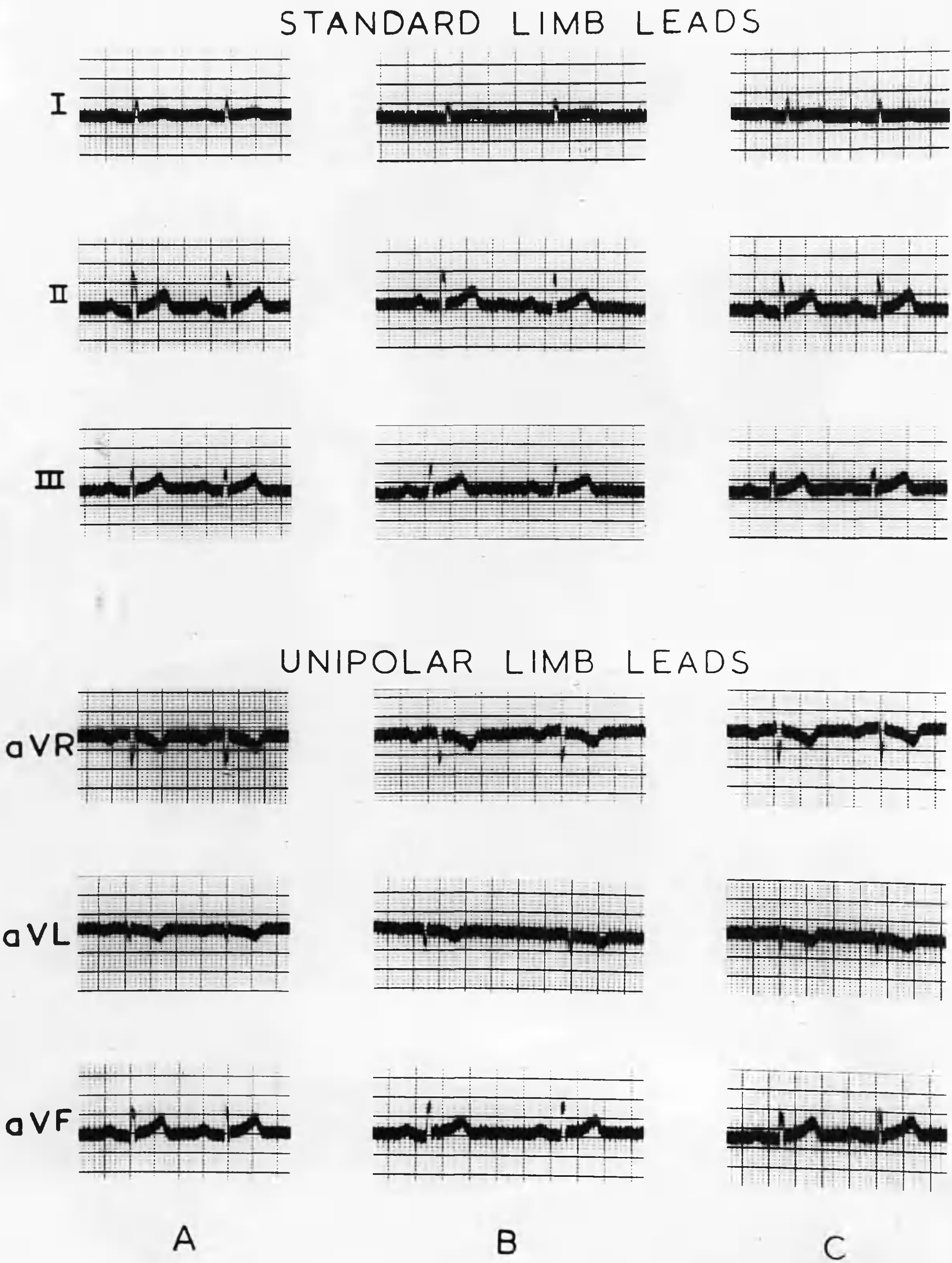
SUMMARY.

This is a normal vertical heart with moderate counter-clockwise rotation.

On inspiration no significant change occurs.

On expiration the heart becomes slightly less vertical and there is possibly slight counter-clockwise rotation.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.3

NORMAL.

J.S.

Age 45 years.

STANDARD LIMB LEADS.

A:Control.

All leads have upright P and T waves and a qRs pattern. There is no axis deviation.

B:Inspiration.

Lead I has a flat P wave and a qR pattern with reduction in the height of R; T is unaltered.

Lead II has a qRs pattern with slight reduction in the amplitude of all deflections; P and T are unaltered.

Lead III has an Rs pattern with increase in the height of R; P and T are unaltered.

There has been a slight shift of the QRS axis to the right.

C:Expiration.

All leads are identical with the control.

UNIPOLAR LIMB LEADS.

A:Control.

aVR has inverted P and T waves and an rSr' pattern.
aVL has inverted P and T waves and an rsr' pattern.
aVF has upright P and T waves and a qRs pattern.
The heart is semi-vertical.

B:Inspiration.

aVR still has an rSr' pattern though the r and r' waves are less obvious: S is slightly reduced. T is slightly less inverted.

aVL has a QS pattern. T is slightly less inverted.

aVF has an Rs pattern with increase in size of R. T is slightly smaller.

The heart has become more vertical.

C:Expiration.

The patterns are the same as in the control series but the S in aVR is slightly deeper and aVL has an rSr' pattern.

PLATE 93b.

PRECORDIAL LEADS.

A:Control.

Leads VI to V3 have RS patterns.
Leads V4 to V6 have qRs patterns.
All have upright T waves.

B:Inspiration.

The patterns are in general similar to the control series. In VI and V2 however R,S and T are all increased in amplitude, while in V3 to V6 they are decreased.

This indicates some clockwise rotation with recession of the apex from the chest wall.

C:Expiration.

The patterns are very similar to those of the control series. In V3 to V6 however R and T are slightly increased in size.

This indicates some degree of counter-clockwise rotation.

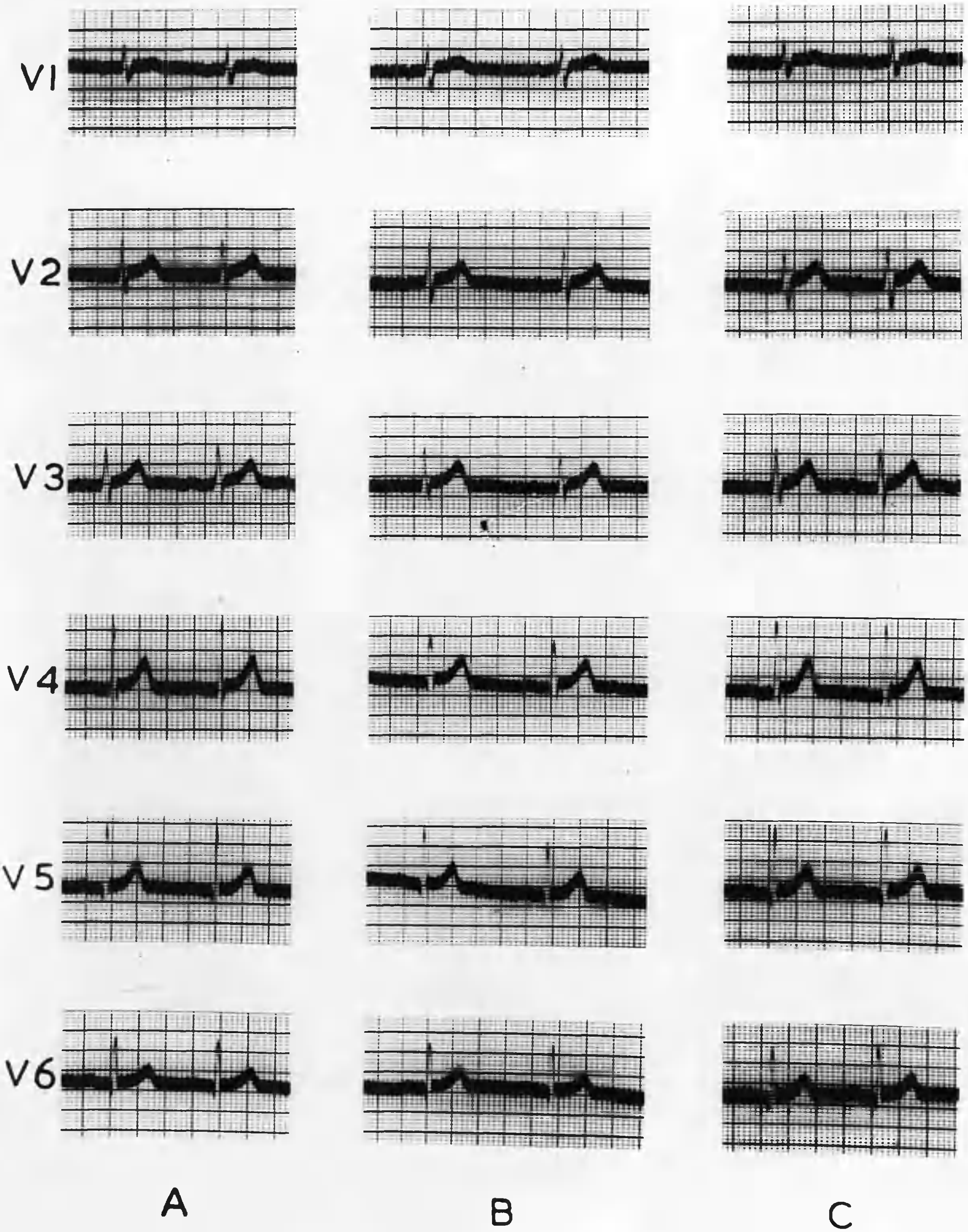
Summary.

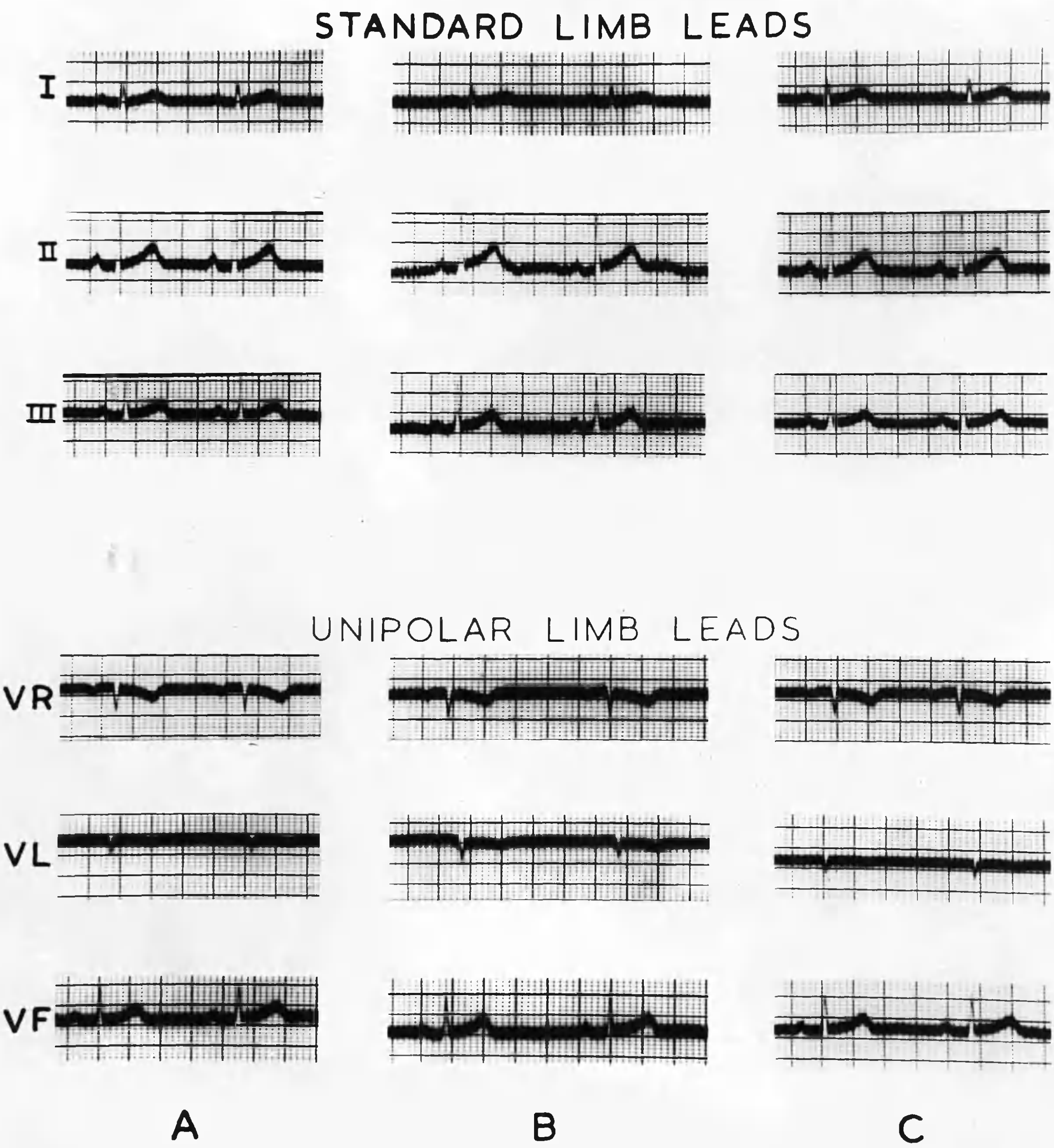
This is a normal semi-vertical heart with moderate counter-clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation round its long axis.

On expiration the reverse changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
A
B
C

CASE NO. 4

NORMAL.

R.R.

Age 24 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Lead I has a qRs pattern.
Lead II has a qRs pattern.
Lead III has an Rs pattern.
There is a tendency to right axis deviation.

B: Inspiration.

The patterns are similar to the control series but lead I shows slight decrease in R and T while lead III shows an increase in R and T.

There has been e shift of the QRS axis to the right.

C: Expiration.

The patterns are similar to the control series.

UNIPOLAR LIMB LEADS.

A: Control.

VR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VL has shallow inverted P and T waves and a qs pattern. It faces the cavity of the left ventricle.

VF has upright P and T waves and an R pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

VR has less inverted P and T waves.

VL has a deeper QS pattern and more deeply inverted P and T waves.

VF has a taller R pattern; P and T are increased.

The heart has become more vertical.

C: Expiration.

The patterns are identical with the control series.

PLATE 94b

PRECORDIAL LEADS.

A: Control.

V1 has an rS pattern.
V2 has an RS pattern.
V3 has an Rs pattern.
V4 and V5 have qRs patterns.
V6 has a qR pattern.
P and T are upright in all leads.

B: Inspiration.

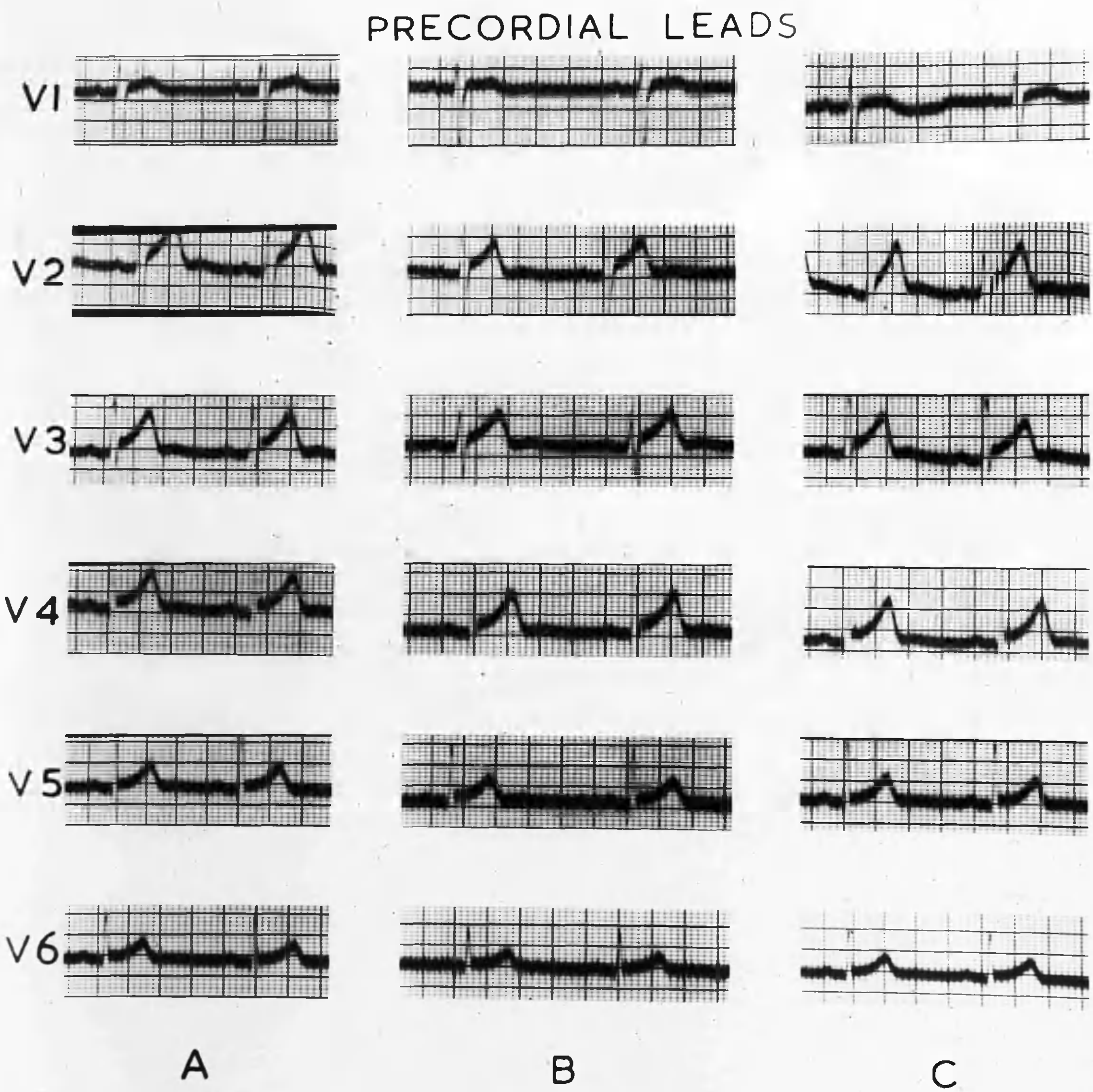
V1 has an rS pattern.
V2 and V3 have RS patterns with decrease in R and increase in S.
V4 to V6 have qRs patterns with decrease in R and increase in s.
T is decreased in V1,V2,V3 and V6.
There has been clockwise rotation.

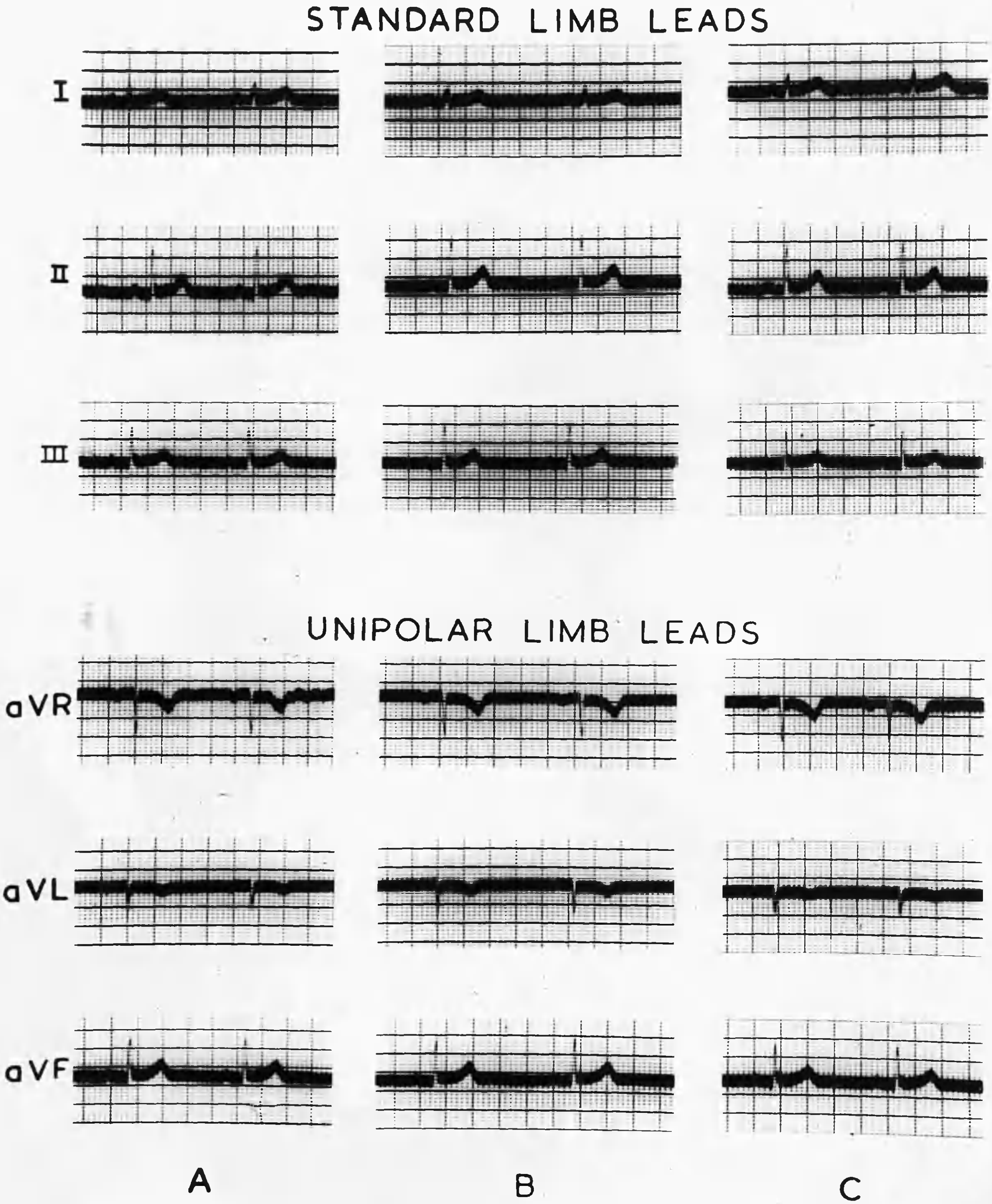
C: Expiration.

The patterns are identical with the control series.

SUMMARY.

This is a normal vertical heart with moderate counter-clockwise rotation.
On inspiration the heart becomes slightly more vertical and undergoes clockwise rotation.
On expiration no obvious changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

NORMAL.

D.L.

Age 31 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves. Lead I has a small Rs pattern; lead II has a qR pattern; lead III has a qR pattern.

There is a tendency to right axis deviation.

B: Inspiration.

Lead I shows smaller R and bigger s; T is reduced.

Lead II shows a qRs pattern with increase in R; T is increased.

Lead III shows increase in R and T

There has been a shift of the QRS axis to the right.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rS pattern. It faces the cavity of the right ventricle.

aVL has shallow inverted P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR is unaltered.

aVL has smaller r, deeper S and deeper T.

aVF has a qRs pattern with increase in R; T is increased.

The heart has become more vertical.

C: Expiration.

All leads are identical with the control series.

PLATE 95b.

PRECORDIAL LEADS.

A: Control.

VI to V3 have rS patterns.

V4 has an RS pattern.

V5 and V6 have qRs patterns.

P and T are upright in all leads; T is maximum in V2.

B: Inspiration.

VI to V4 have rS patterns.

V5 and V6 have qRs patterns with reduction in q and R and deeper s.

P and T are upright in all leads; T is maximum in V3.

There has been clockwise rotation.

C: Expiration.

All leads are identical with the control series.

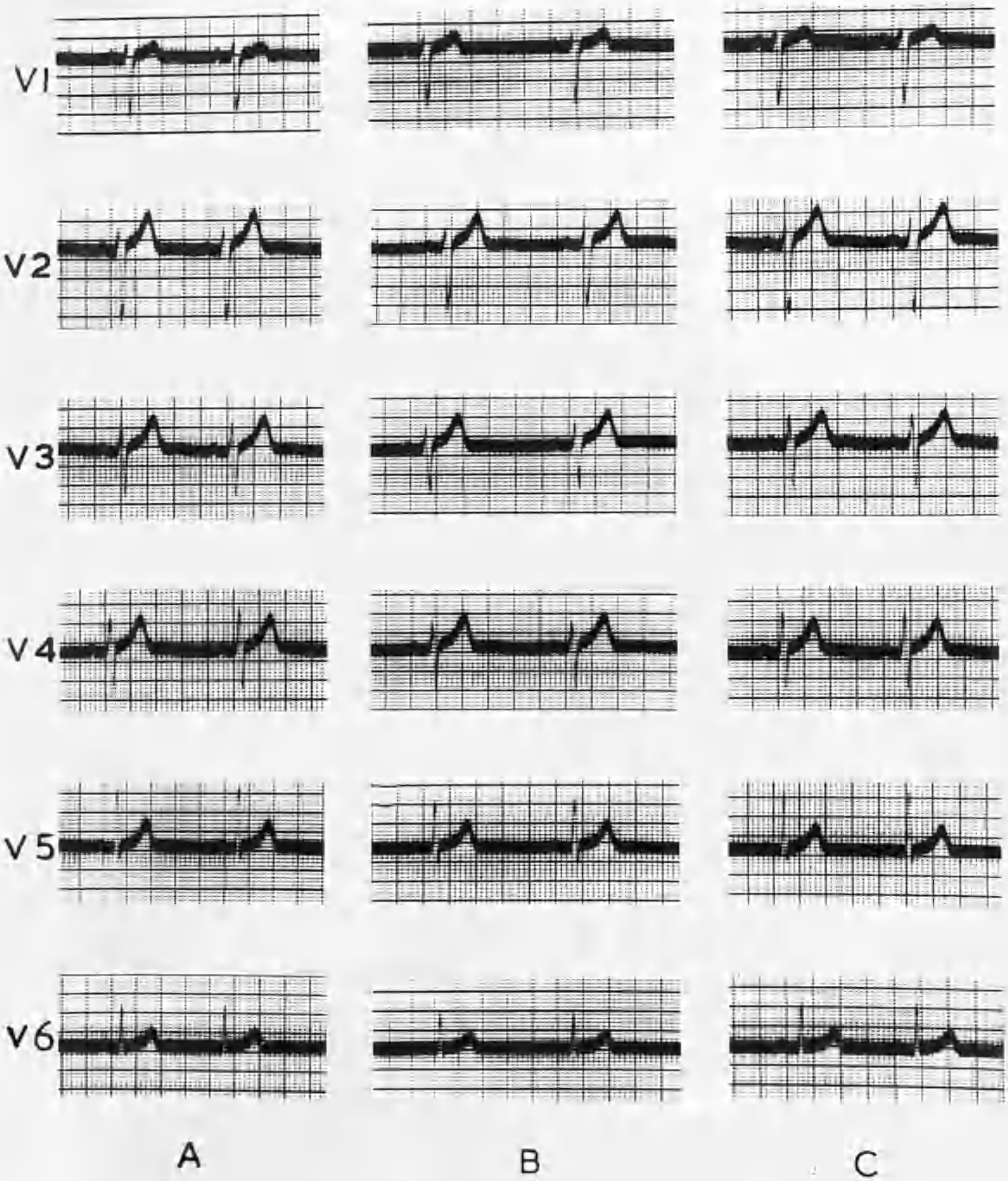
SUMMARY.

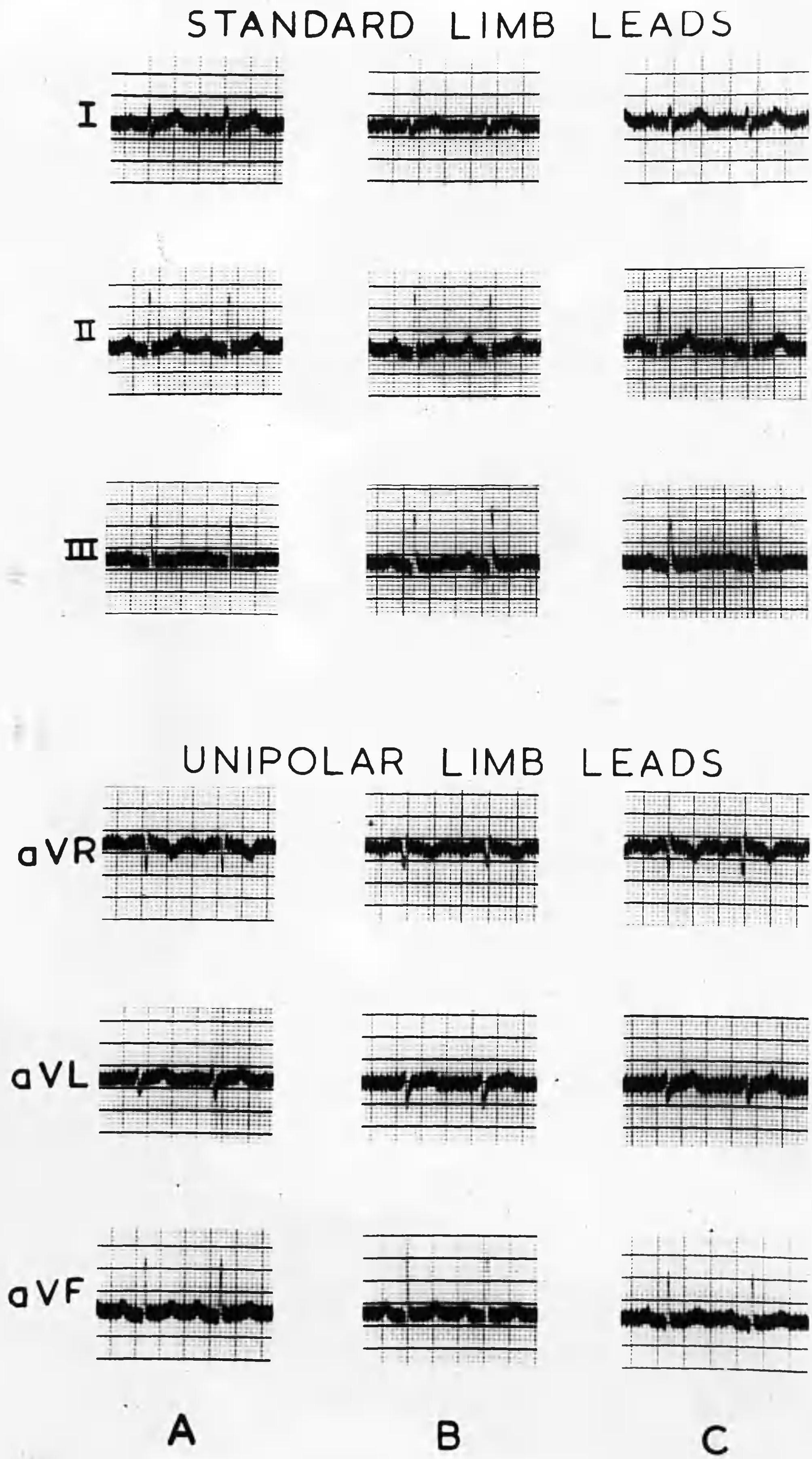
This is a normal vertical heart with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and there is clockwise rotation.

On expiration the heart shows no significant changes.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.6

NORMAL.

Miss H.L.

Age 2I years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and a small RS pattern.

Lead II has upright P and T waves and a qRs pattern.

Lead III has upright P and shallow diphasic T waves and a qR pattern.

There is right axis deviation.

B: Inspiration.

The basic patterns are unaltered, but lead I has smaller R and T; lead II has taller R and smaller T; lead III has taller P and R and T is more diphasic.

There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a Qr pattern. It is tending to face the back of the heart.

aVL has flat P and upright T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

The basic patterns are unaltered but aVR has less inverted P and T waves, smaller Q and bigger r; aVL has smaller r, deeper S and smaller T; aVF has taller R and T.

The heart has become more vertical and there has been clockwise rotation so that aVR actually faces the back of the heart.

C: Expiration.

The only change from the control is a decrease of R in aVF.

The heart has become slightly less vertical.

PLATE 96b

PRECORDIAL LEADS.

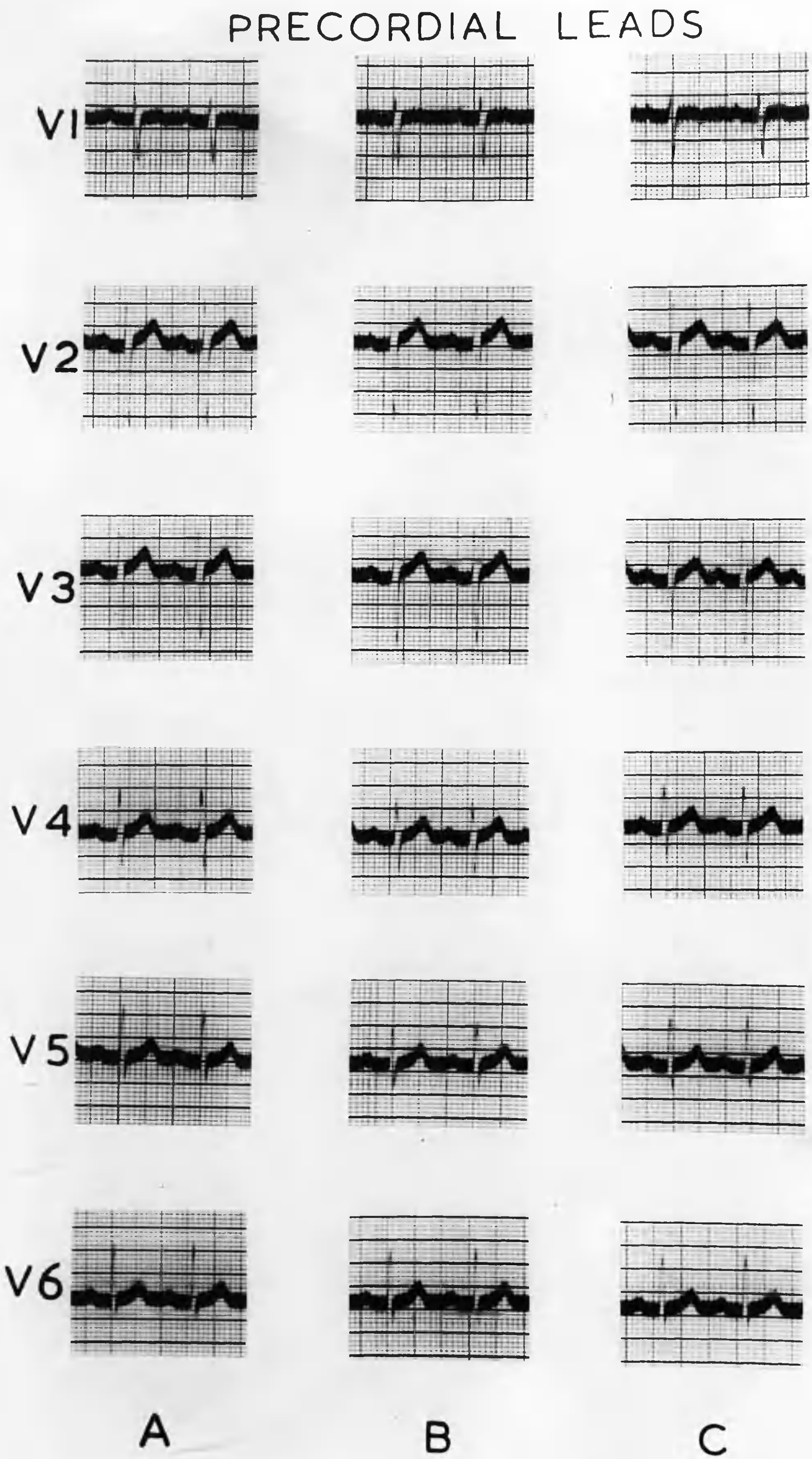
A: Control.
VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qRs pattern.
P is upright in all leads.
T is slightly diphasic in VI and upright in all other leads.

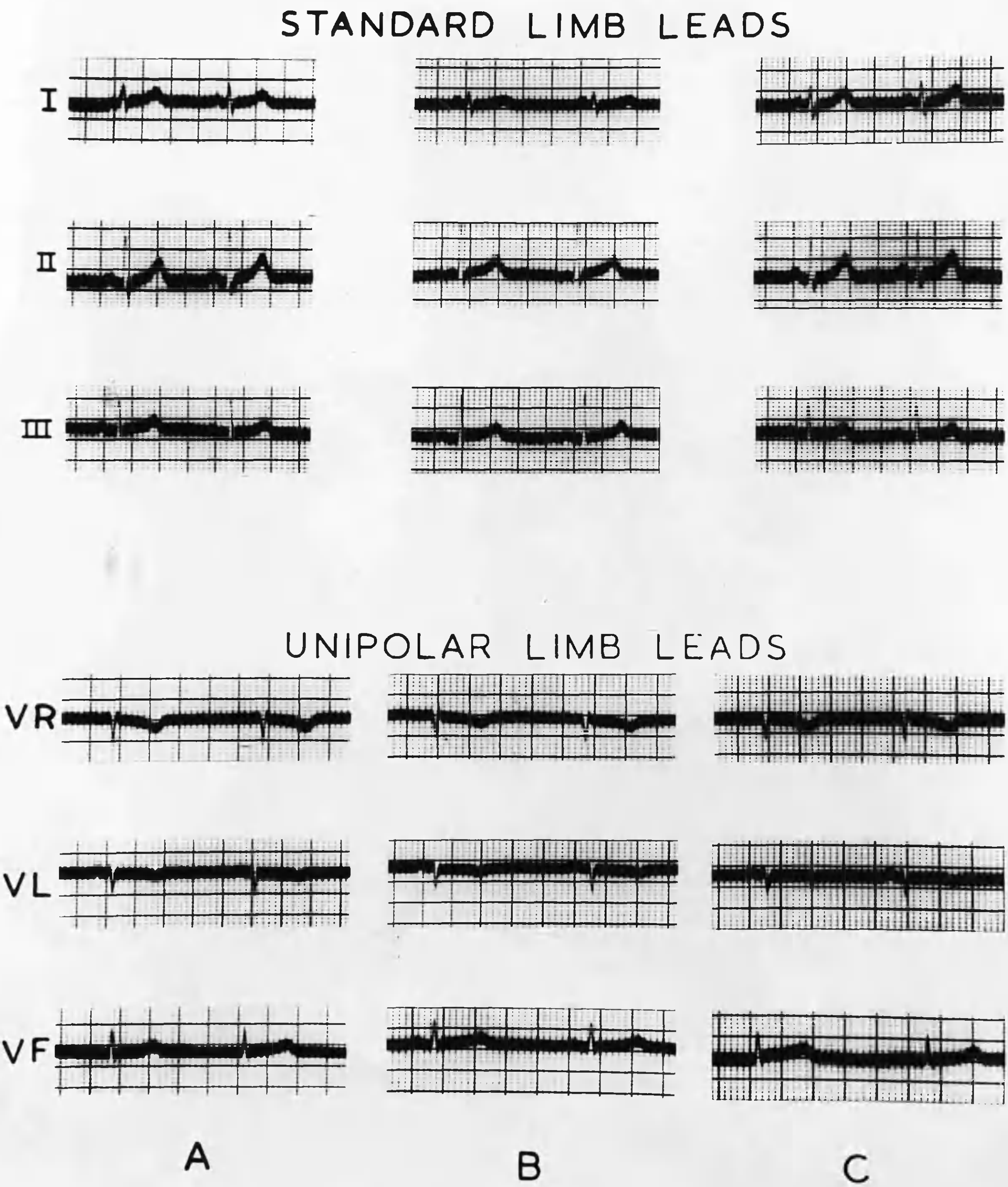
B: Inspiration.
VI to V3 have rS patterns with reduction in r and slight increase in S.
V4 has an RS pattern with reduction in R.
V5 and V6 have Rs patterns with reduction in R and increase in s.
There has been some clockwise rotation.

C: Expiration.
The patterns show no change from the control series.

SUMMARY.

This is a normal vertical heart with moderate clockwise rotation and forward rotation of the apex.
On inspiration the heart becomes more vertical and undergoes clockwise rotation.
On expiration the heart becomes slightly less vertical.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
A
B
C

CASE NO.7

NORMAL.

W.R.

Age 26 years.

STANDARD LIMB LEADS.

A: Control

Lead I has upright P and T waves and an Rs pattern.

Lead II has upright P and T waves and a qRs pattern.

Lead III has diphasic P and upright T waves and a qRs pattern.

There is a tendency to right axis deviation.

B: Inspiration.

Lead I shows an RS pattern with reduction in R. T is reduced.

Lead II has a qRs pattern with increase in R. P is diphasic and T is reduced.

Lead III has a qRs pattern with increase in R.

There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are similar to those of the control series but lead I shows a slight increase in R and T while lead III shows a decrease in R and T.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control

VR has inverted P and T waves and a Qr pattern. It tends to face the back of the heart.

VL has upright P and inverted T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has flat P and upright T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

VR shows less inversion of T.

VL has a QS pattern.

VF is unchanged.

The heart has become slightly more vertical.

C: Expiration.

The patterns are identical with the control series.

PLATE 97b

PRECORDIAL LEADS.

A: Control.

VI has an rS pattern.
V2 and V3 have RS patterns.
V4 has an Rs pattern.
V5 and V6 have qRs patterns.
P and T are upright in all leads.

B: Inspiration.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have Rs patterns with reduction in R and increase in s.
T is reduced in V2 to V6.
There has been considerable clockwise rotation.

C: Expiration.

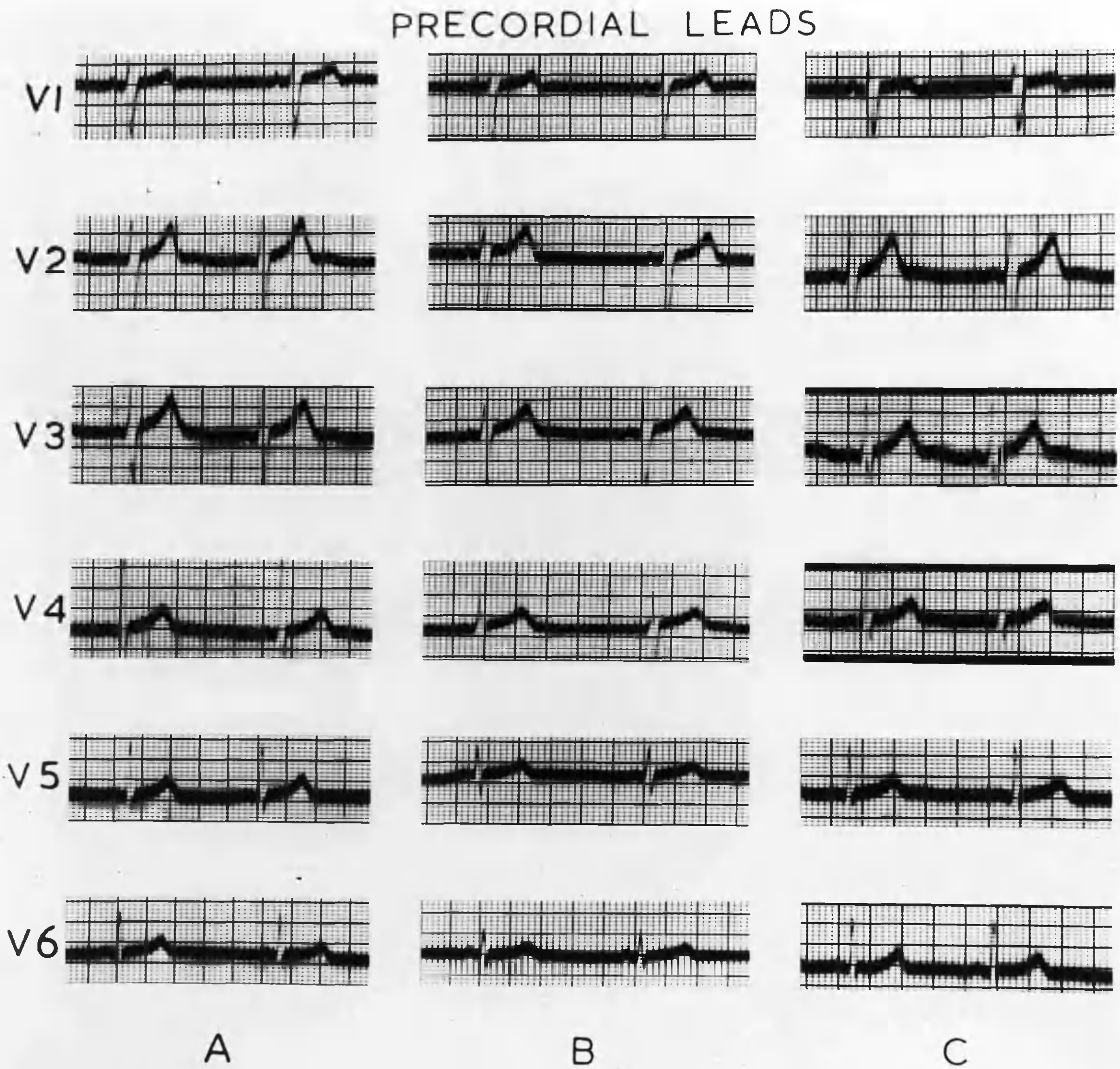
VI has an rS pattern with reduction in S.
V2 and V3 have RS patterns with increase in R.
V4 has an Rs pattern with reduction in s.
V5 and V6 have qRs patterns with increase in R and reduction in s.
There has been some counter-clockwise rotation.

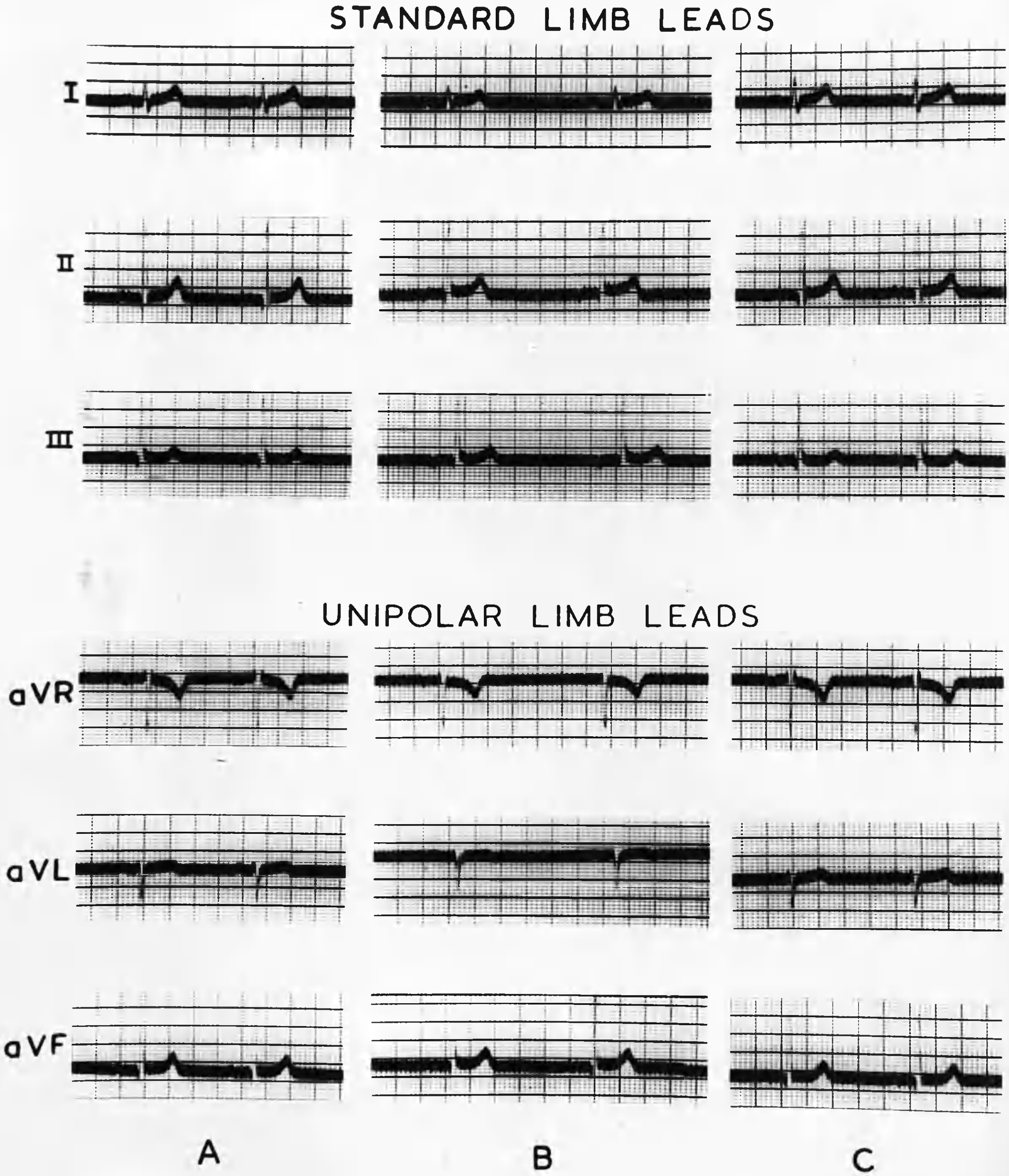
SUMMARY.

This is a normal vertical heart with moderate clockwise rotation.

On inspiration the heart undergoes considerable clockwise rotation but shows little or no tendency to become more vertical.

On expiration the heart undergoes slight counter-clockwise rotation.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 8 PLATE 98a

NORMAL. D.W.

Age 20 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an Rs pattern.

Lead II has diphasic P and upright T waves and a qRs pattern.

Lead III has diphasic P and upright T waves and a qR pattern.

There is slight right axis deviation.

B: Inspiration.

The basic patterns are unaltered but lead I shows decrease in P,R,s and T; lead II shows decrease in R,s and T; lead III shows inversion of P, decrease in q and increase in T.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.

aVL has upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has diphasic P and upright T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR shows reduction of S,r' and T.

aVL shows reduction in P and r; T is flat or slightly inverted.

aVF shows increase in R and T.

The teart has become more vertical.

C: Expiration.

The patterns are identical with the control series but S and T are increased in aVR while R and T are decreased in aVF.

The heart has become less vertical.

PLATE 98b

PRECORDIAL LEADS.

A: Control.

VI to V3 have RS patterns.
V4 has an Rs pattern.
V5 and V6 have qRs patterns.
P is diphasic and T upright in all leads.

B: Inspiration.

VI to V4 have RS patterns.
V5 has an Rs pattern with reduction in R.
V6 has a qRs pattern with reduction in R.
T is maximum in V3 instead of V2 and is increased in V4 to V6.

There has been clockwise rotation of the heart.

C: Expiration.

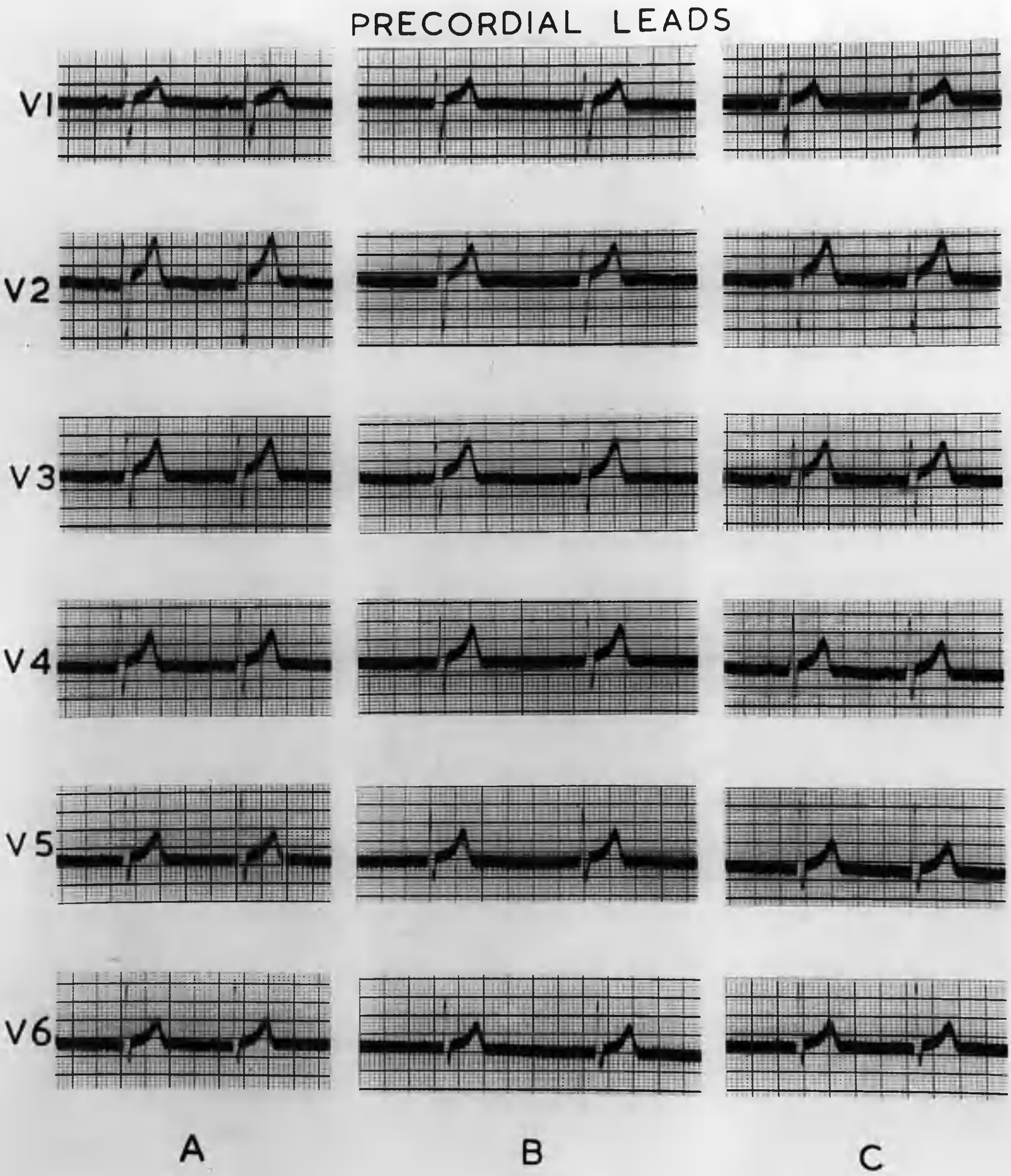
The patterns are identical with the control series.

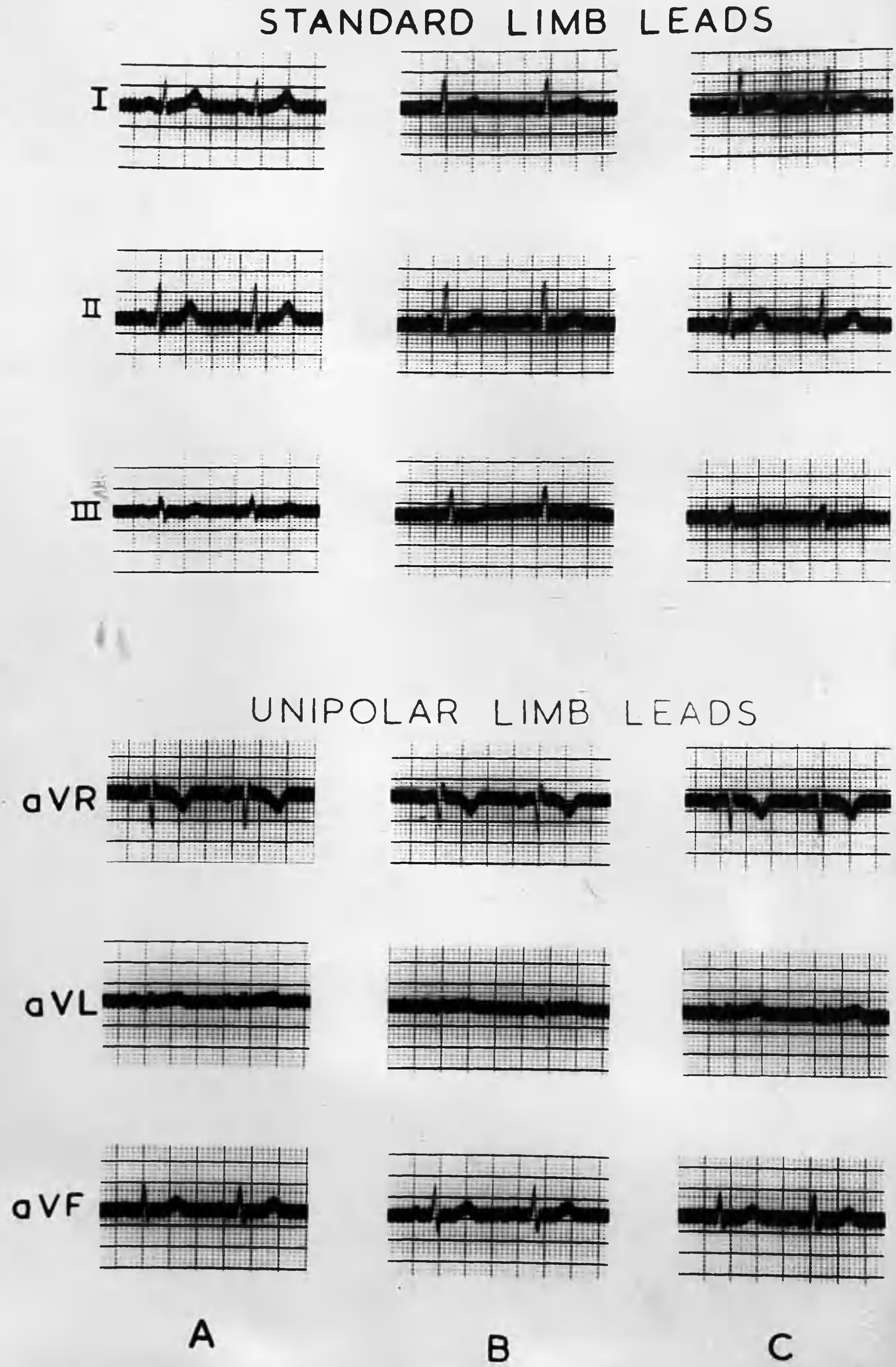
SUMMARY.

This is a normal vertical heart with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation.

On expiration the heart becomes slightly less vertical.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 9 PLATE 99a

NORMAL. R.C.

Age 28 years.

STANDARD LIMB LEADS

A: Control.

Lead I has upright P and T waves and a qRs pattern.

Lead II has upright P and T waves and a qRs pattern.

Lead III has diphasic P and upright T waves and a qRs pattern.

B: Inspiration.

Lead I shows smaller P and T waves and a qR pattern.

Lead II has an Rs pattern with increase in R and decrease in s; T is reduced.

Lead III has an Rs pattern with increase in R and decrease in s; T is smaller.

There has been a shift of the QRS axis to the right.

C: Expiration.

Lead I has an R pattern with increased amplitude; T is smaller.

Lead II is identical with the control apart from a decrease in height of T.

Lead III is identical with the control apart from decrease in R.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.

aVL has upright P and T waves and a qrsr' pattern.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is semi-vertical.

B: Inspiration.

aVR shows a Qr pattern. It tends to face the back of the heart.

aVL shows reduction in T but no other change.

aVF still shows a qRs pattern with increase in R and s.

These changes are due to clockwise rotation of the heart.

C: Expiration.

These are identical with the control series.

PRECORDIAL LEADS.

A: Control.

V1 to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns.
P is upright in all leads.
T is slightly inverted in V1 and upright in all other leads.

B: Inspiration.

V1 to V3 have rS patterns with reduction of r and increase of S in V3.
V4 has an RS pattern with reduction of R and increase of S.
V5 has an Rs pattern with increase of R and s.
V6 has a qRs pattern with reduction of R and increase of s.
There has been clockwise rotation.

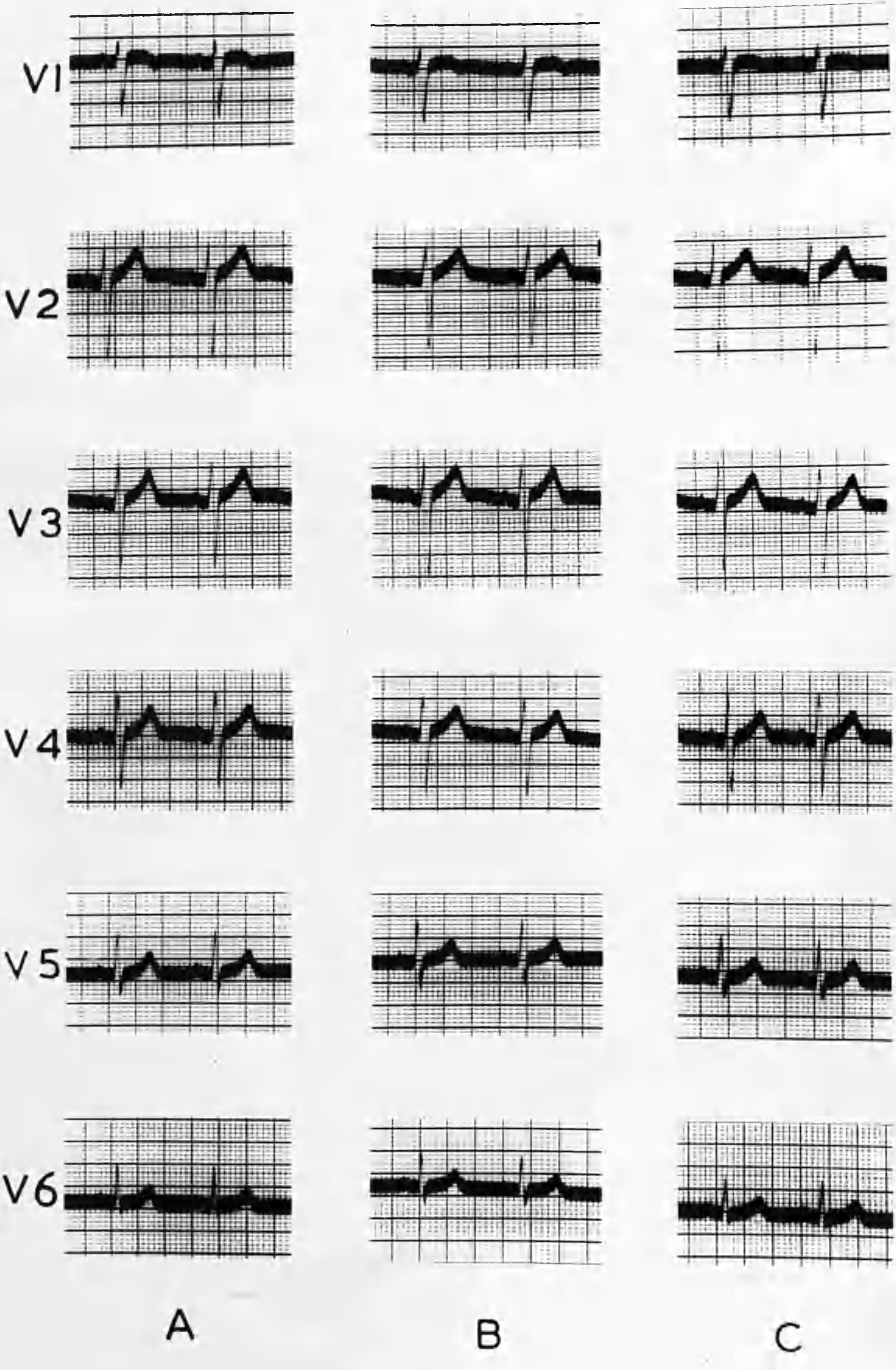
C: Expiration.

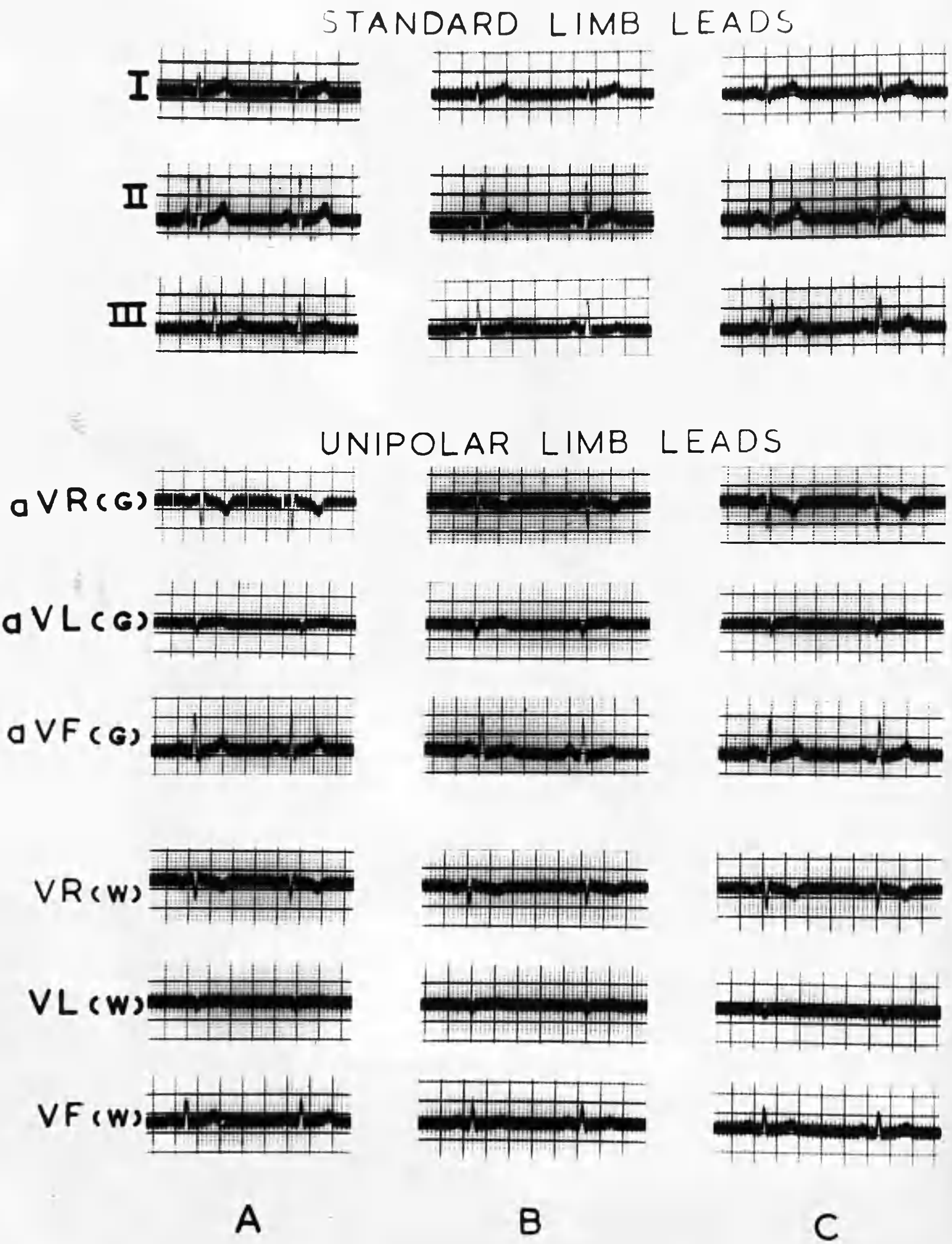
All leads are identical with the control series.

SUMMARY.

This is a normal semi-vertical heart with moderate clockwise rotation.
On inspiration the heart undergoes clockwise rotation.
On expiration no significant change occurs.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR (G)
aVL (G)
aVF (G)
VR (W)
VL (W)
VF (W)
A
B
C

NORMAL. W.McG.

Age 34 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Leads I and II have qRs patterns.
Lead III has an Rs pattern.

B: Inspiration.

Lead I shows smaller R and larger s. P and T are reduced.

Lead II shows smaller R and s. P and T are reduced.

Lead III shows a qRs pattern with increase in R. T is reduced.

There has been a shift of the QRS axis to the right.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It tends to face the epicardial surface of the right ventricle.

aVL has shallow inverted P and low upright T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical with forward rotation of the apex.

B: Inspiration.

aVR shows smaller S and less inverted P and T.
aVL has a QS pattern and upright T.
aVF shows smaller T.
These changes may be due to clockwise rotation.

C: Expiration.

The patterns are identical with the control series.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PLATE IOOb

PRECORDIAL LEADS.

A: Control.

VI has an RS pattern varying with respiration.

V2 and V3 have rS patterns, S varying with respiration.

V4 has an Rs pattern.

V5 and V6 have qRs patterns.

P is upright in all leads.

T in VI is upright or inverted varying with respiration. It is upright in all other leads.

B: Inspiration.

VI has an RS pattern.

V2 and V3 have rS patterns with reduction in S.

V4 has an RS pattern with reduction in R.

V5 and V6 have qRs patterns with reduction in q and R and increase in s.

T is upright in all leads.

There has been clockwise rotation.

C: Expiration.

VI to V3 have rS patterns.

V4 has an Rs pattern.

V5 and V6 have qRs patterns.

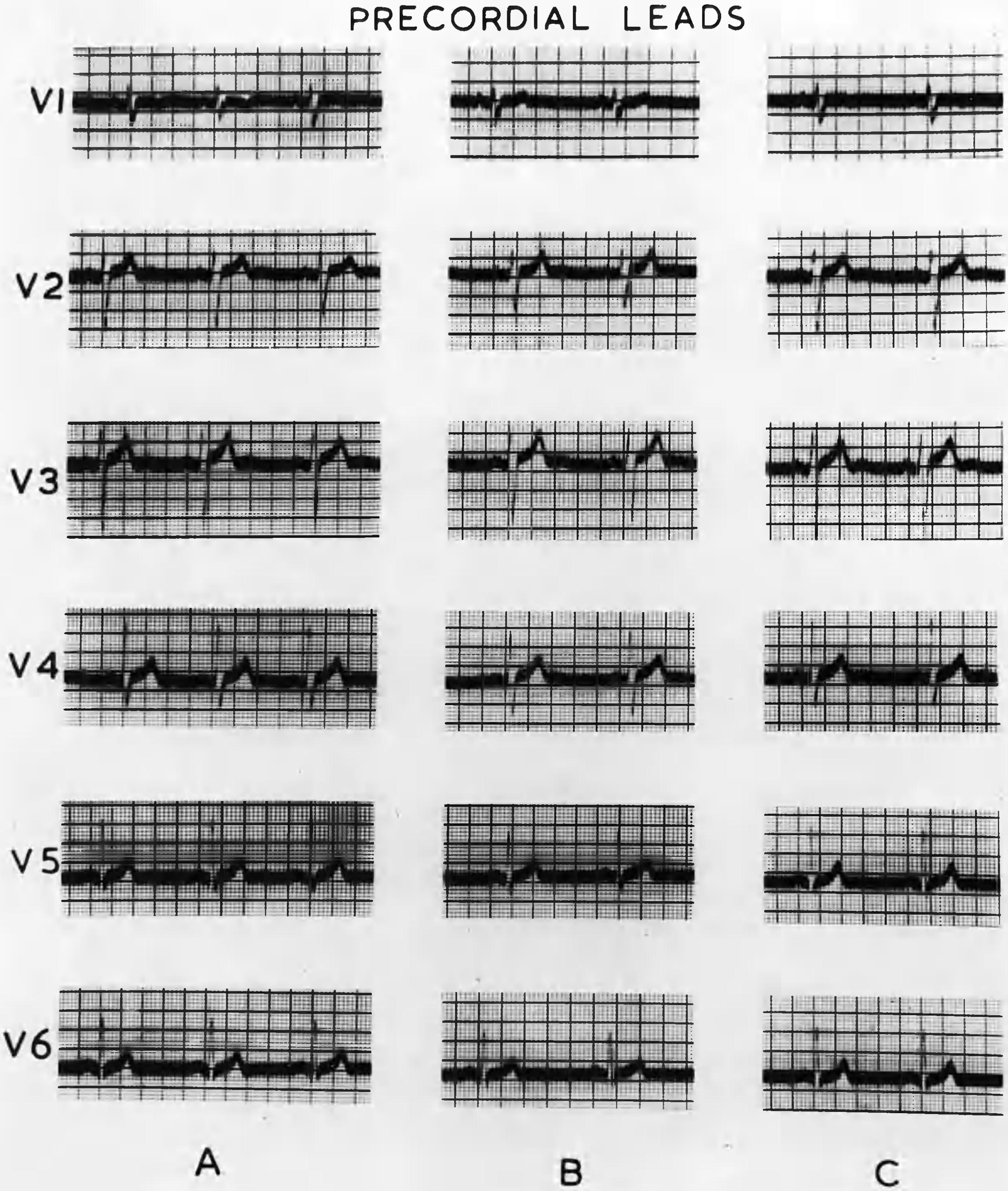
T is shallow and diphasic in VI and upright in all other leads.

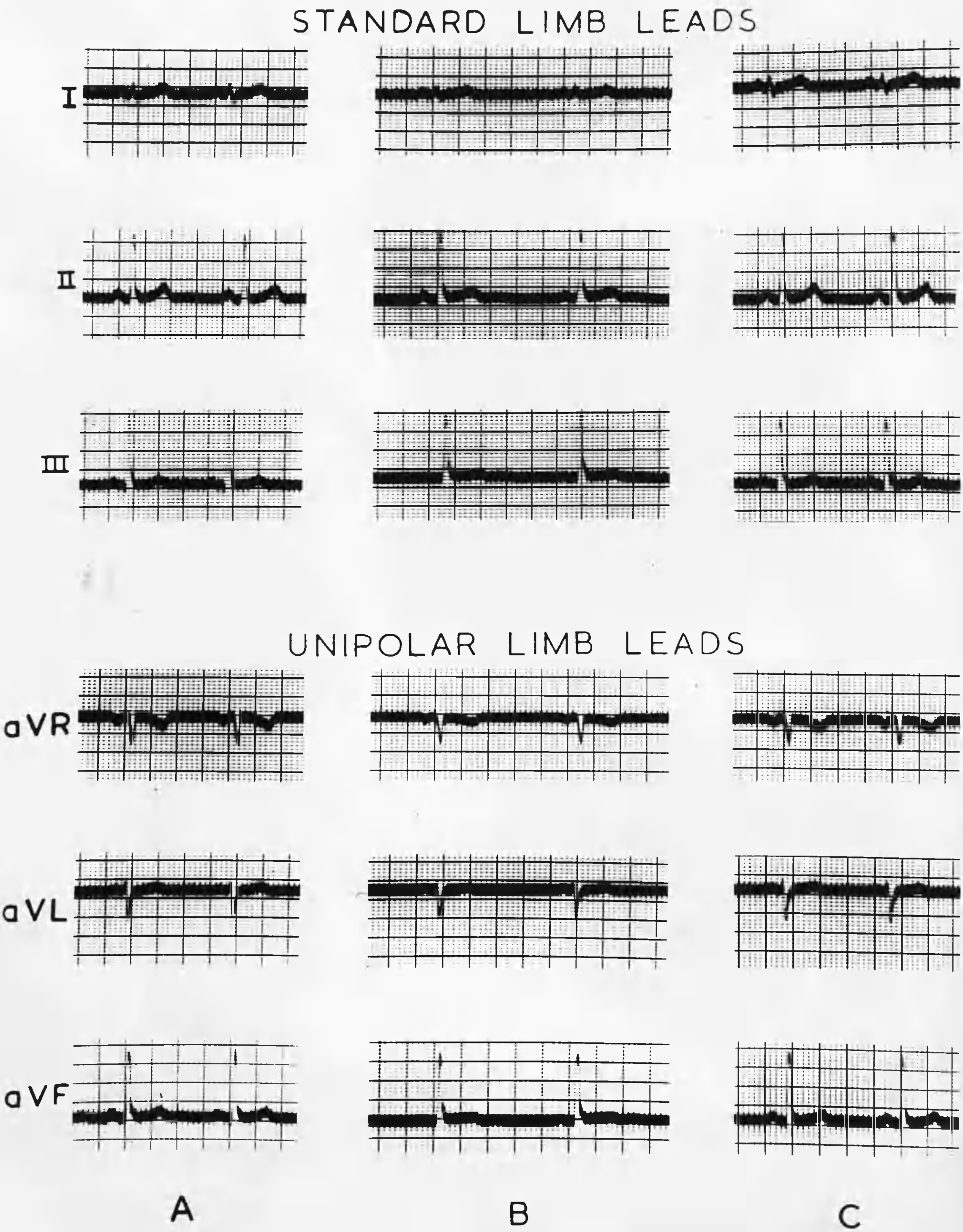
SUMMARY.

This is a normal vertical heart with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart undergoes clockwise rotation and backward rotation of the apex.

On expiration no significant changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. II PLATE IOIa

NORMAL. T.L.

Age 27 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.

Lead I has a small Rs pattern; lead II has an R pattern; lead III has a qR pattern.

There is right axis deviation.

B: Inspiration.

The basic patterns are unaltered but lead I shows reduction in P,R,s and T; lead II shows reduction in P and T; lead III shows reduction in P and T.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has low upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR shows reduction in P and T and slight reduction in depth of QS.

aVL shows reduction in r and T.

aVF shows reduction in P and T and has an R pattern.

The heart has become slightly more vertical and there has been clockwise rotation.

C: Expiration.

The patterns are identical to the control series.

PLATE IOIb

PRECORDIAL LEADS.

A: Control.

VI and V2 have rS patterns.
V3 has a splintered RS pattern.
V4 has an RSR'S' pattern.
V5 has an Rs pattern.
V6 has an R pattern.
P and T are upright in all leads.

B: Inspiration.

VI and V2 have rS patterns with reduction in r.
V3 and V4 have notched RS patterns.
V5 has a notched Rs pattern with reduction in R.
V6 has an Rs pattern with reduction in R.
T is increased in VI and reduced in V5 and V6.
There has been clockwise rotation of the heart.

C: Expiration.

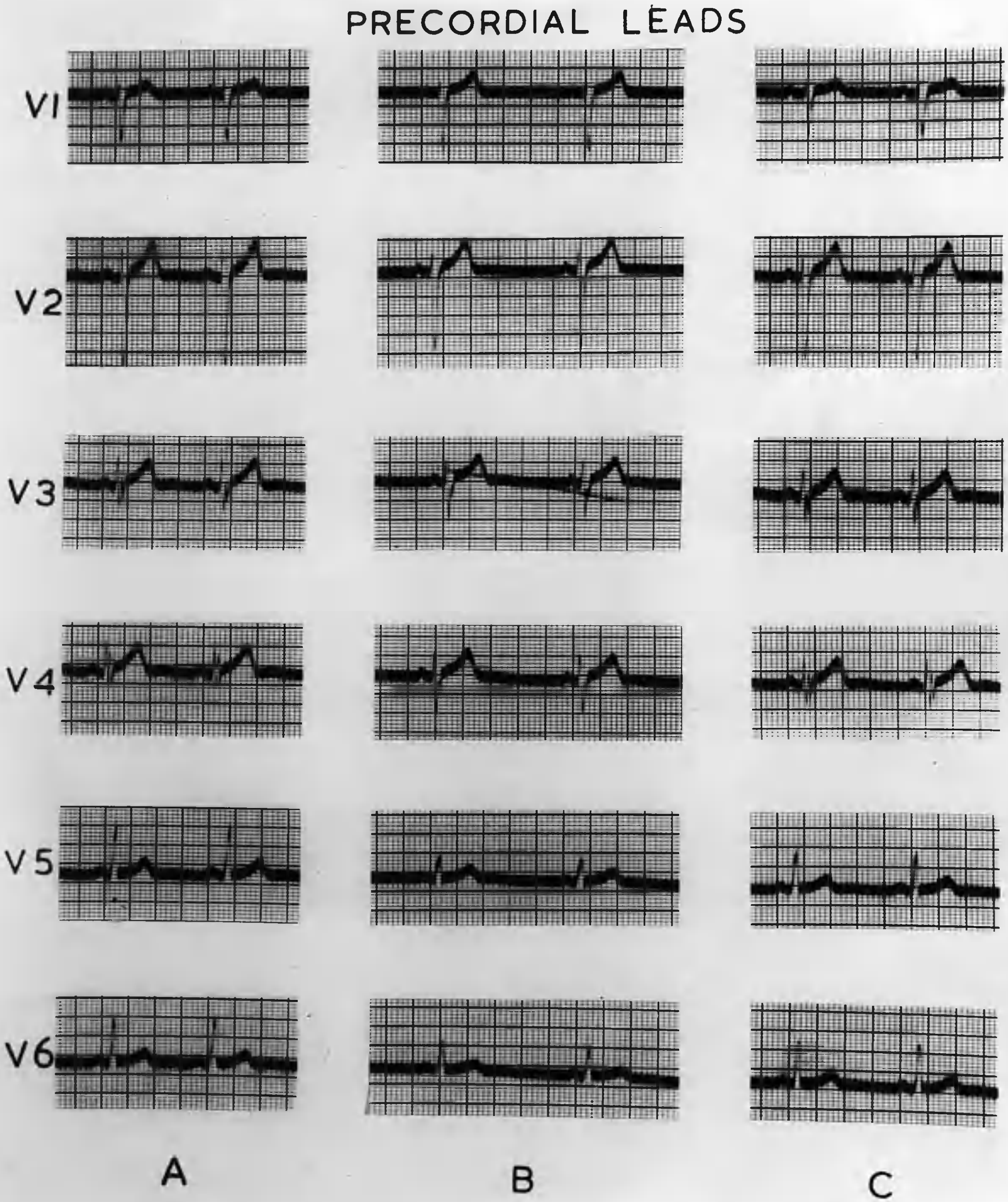
The patterns are identical with the control series apart from slight reduction of R in V5 and V6.

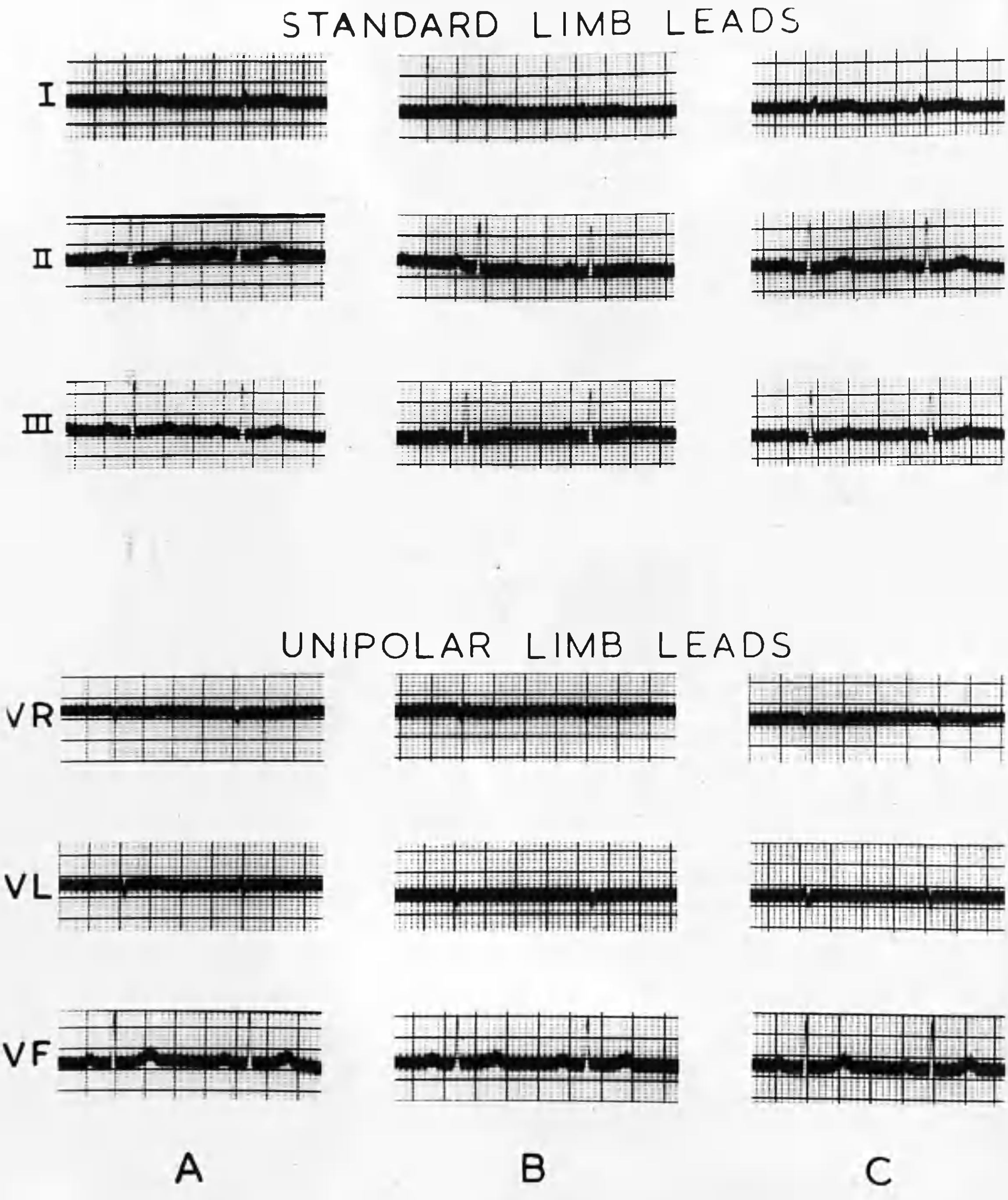
SUMMARY.

This is a normal vertical heart with marked clockwise rotation and forward rotation of the apex.

On inspiration the main change is clockwise rotation. The heart may also have become slightly more vertical.

On expiration no obvious changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
A
B
C

NORMAL.

J.H.

Age 28 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Lead I has a small Rs pattern.
Lead II has an Rs pattern.
Lead III has a qRs pattern.
There is right axis deviation.

B: Inspiration.

Lead I shows decrease in P,R and T.
Lead II shows an R pattern and reduction in T.
Lead III shows a qR pattern with reduction in q.
T is reduced.
There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are identical with the control series but lead I shows slight increase in R and lead III slight decrease in R.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

VR has shallow inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VL has low upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern.

The heart is vertical.

B: Inspiration.

The basic patterns are unaltered.
T is slightly reduced in VF.

C: Expiration.

The tracings are identical with the control series.

PRECORDIAL LEADS.

A: Control.

VI and V2 have rS patterns.
V3 and V4 have RS patterns.
V5 and V6 have Rs patterns.
P is upright in all leads.
T is diphasic in VI and V2 and upright in all other leads.

B: Inspiration.

VI and V2 have rS patterns and r is reduced in V2.
V3 and V4 have RS patterns with reduction in R and increase in S.
V5 and V6 have Rs patterns with reduction in R and increase in s.
T is upright in all leads and is reduced in V4 to V6.
The heart has undergone clockwise rotation.

C: Expiration.

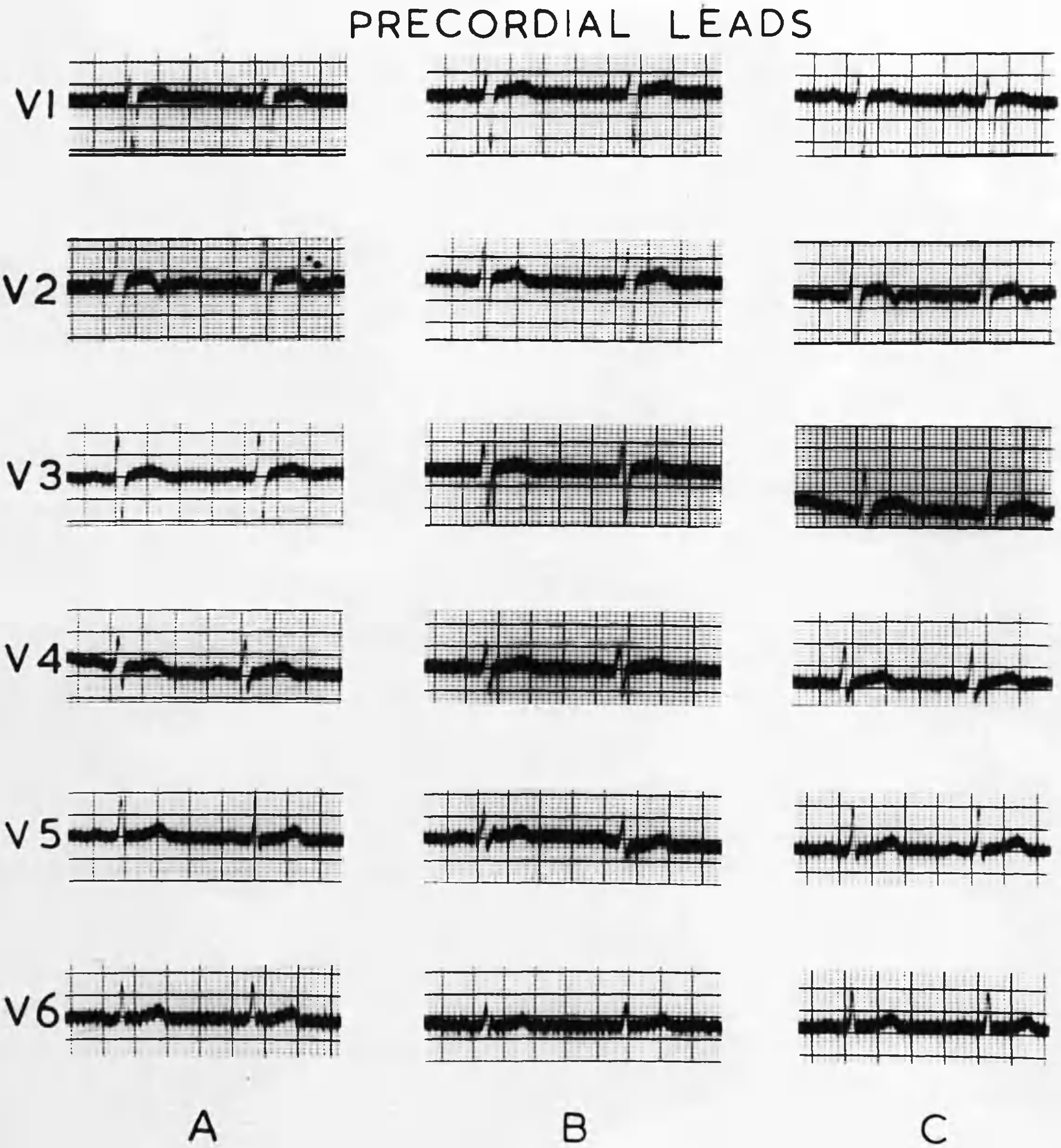
The patterns are similar to the control series but there is increase in R in V4 to V6.
The heart has undergone slight counter-clockwise rotation.

SUMMARY.

This is a normal vertical heart with marked clockwise rotation and forward rotation of the apex.

On inspiration the heart undergoes further clockwise rotation.

On expiration the heart undergoes slight counter-clockwise rotation.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C

CASE NO. 13 PLATE 103a

NORMAL. R.

Age 27 years.

STANDARD LIMB LEADS.

A: Control.

Lead I and lead II have upright P and T waves and a qRs pattern.

Lead III has low upright P and diphasic, mainly inverted T waves and a small Rs pattern.

There is a tendency to left axis deviation.

B: Inspiration.

Lead I shows reduction in P, R, s and T.

Lead II shows reduction in T.

Lead III has upright P and T waves and a tall Rs pattern.

There has been a shift of the QRS axis to the right.

C: Expiration.

Leads I and II are identical with the control series but lead III has diphasic P and inverted T waves and a small vibratory rsr's' pattern.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and T waves and a small vibratory qrsr' pattern. It tends to face the epicardial surface of the left ventricle.

VF has upright P and low upright T waves and a small Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is semi-horizontal.

B: Inspiration.

VR shows a less inverted T wave.

VL shows low inverted P and flat T waves and a Qr pattern. It now faces the back of the heart.

VF shows a taller Rs pattern. T is increased.

The heart has become less horizontal and there has been back-ward rotation of the apex.

C: Expiration.

The patterns are identical with the control series but T is slightly increased in VL and decreased in VF.

PLATE I03b

PRECORDIAL LEADS.

A: Control.

V1 to V3 have rS patterns.

V4 to V6 have qRs patterns.

P and T are upright in all leads.

B: Inspiration.

V1 has an rSr' pattern.

V2 and V3 have rS patterns.

V4 has an RS pattern.

V5 and V6 have qRs patterns with reduction in q and R and increase in s.

P is reduced in all.

T is flat in V1 and reduced in V2,V3,V5 and V6.

The heart has undergone clockwise rotation.

C: Expiration.

The patterns are similar to those of the control series but there is slight reduction of s in V4 to V6.

The heart has undergone slight counter-clockwise rotation.

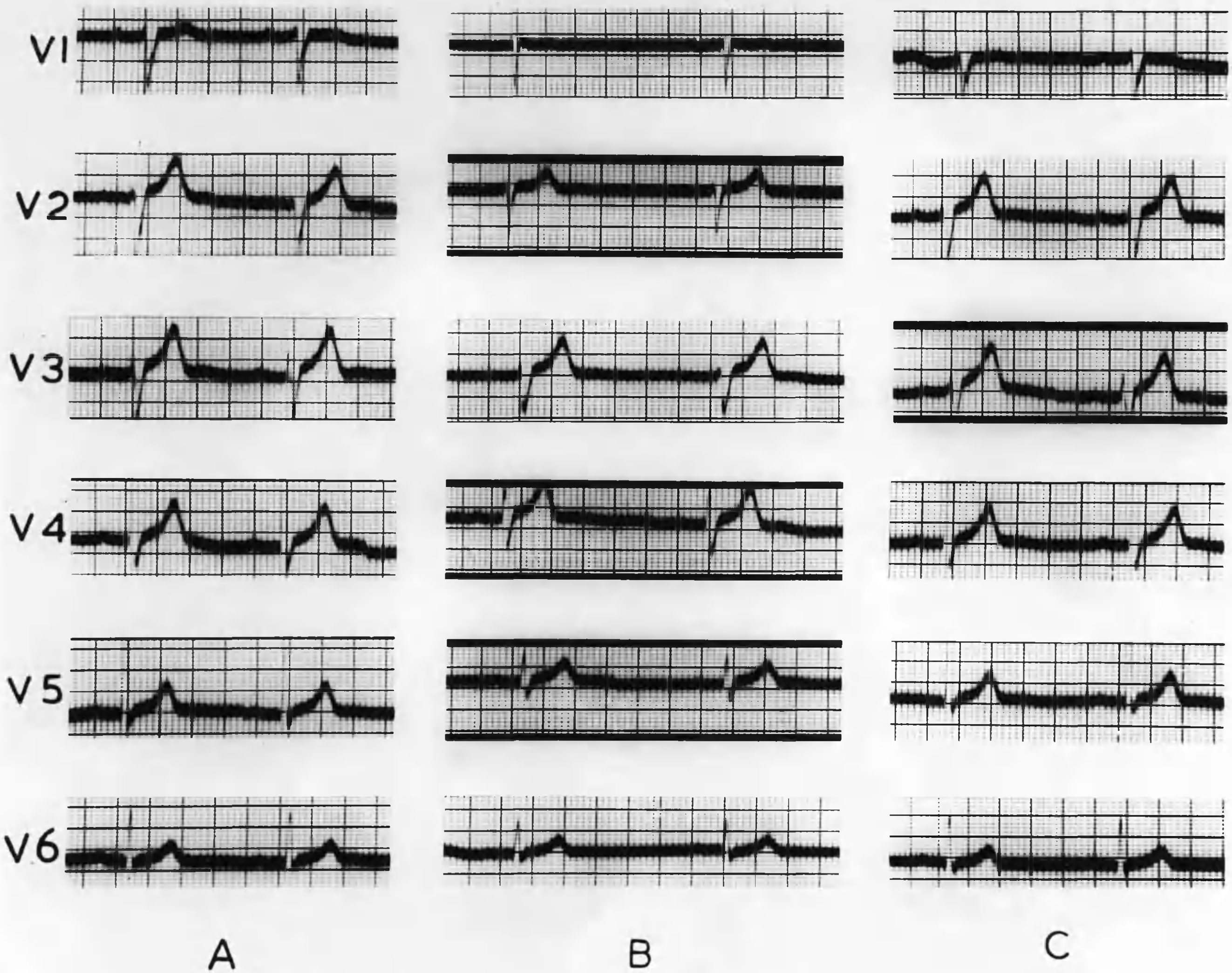
SUMMARY.

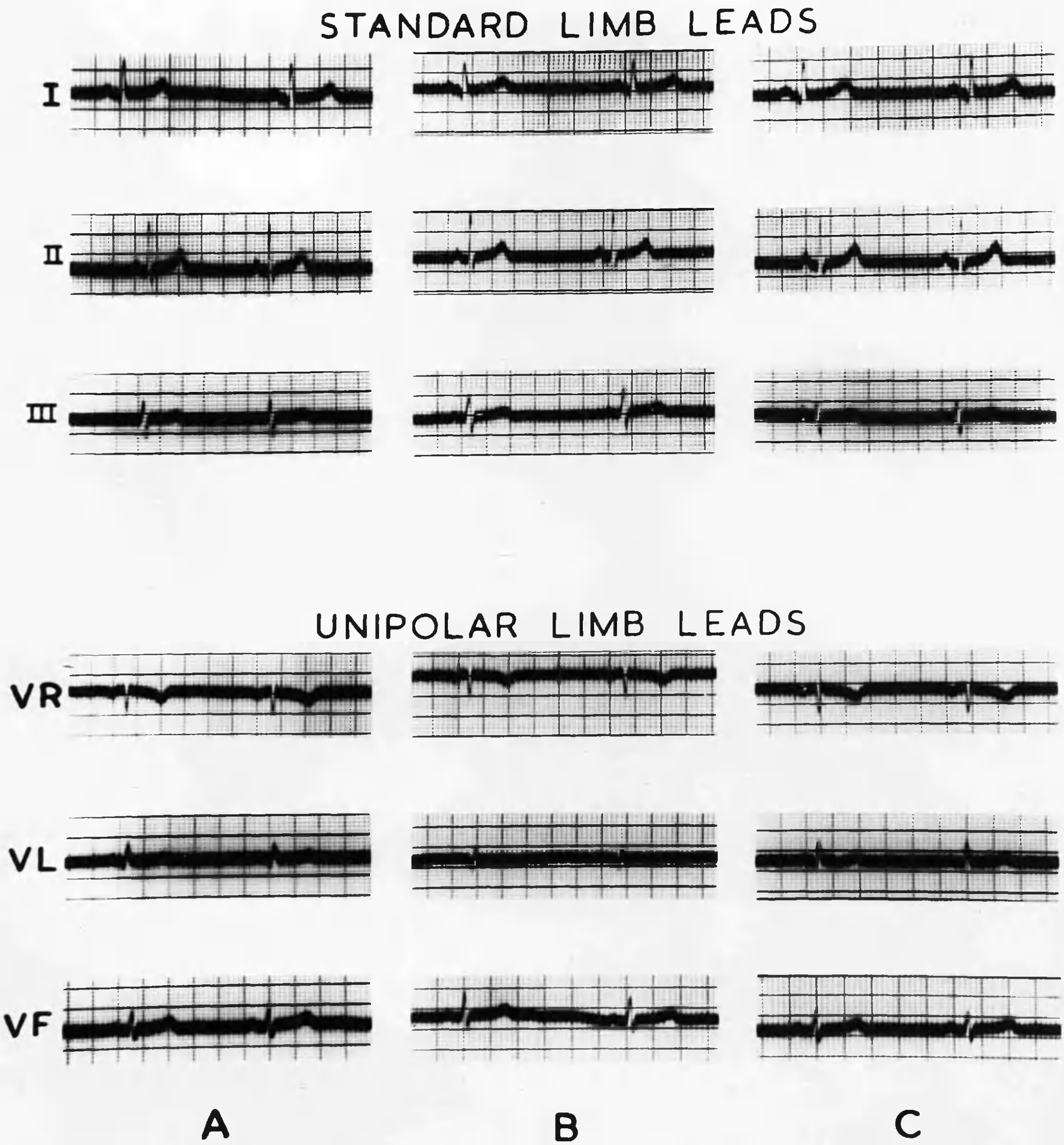
This is a normal semi-horizontal heart with moderate counter-clockwise rotation.

On inspiration the heart becomes less horizontal and undergoes considerable clockwise rotation with backward rotation of the apex.

On expiration the heart undergoes slight counter-clockwise rotation.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
A
B
C

CASE NO. I4 PLATE I04a

NORMAL. A.R.

Age I9 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Lead I has a qR pattern.
Lead II has a qRs pattern.
Lead III has an RS pattern.
There is a tendency to left axis deviation.

B: Inspiration.

The basic patterns are unaltered but lead I shows decrease in P, R and T; lead II shows decrease in q, R and T; lead III shows increase in R and T.

There has been a shift of the QRS axis to the right.

C: Expiration.

The basic patterns are unaltered but lead I shows an increase of P, R and T; lead III shows a decrease in R and an increase in S.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

VR shows inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.

VL has low upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

VF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal.

B: Inspiration.

VR shows less inverted P and T waves.

VL has flat P and T waves and a qR pattern with reduction in R. It is tending to face the back of the heart.

VF still shows an Rs pattern with increase in R.

The heart has become less horizontal and there has been backward rotation of the apex.

C: Expiration.

The patterns are similar to the control series but VR shows increase in S; VL shows increase in R and T; VF shows decrease in R and T.

The heart has become more horizontal.

PLATE I04b

PRECORDIAL LEADS.

A: Control.

VI and V2 have rS patterns.
V3 has an RS pattern.
V4 to V6 have qRs patterns.
P is upright in all leads.
T is slightly diphasic in VI and upright in all other leads.

B: Inspiration.

VI and V2 have rS patterns with increase in S.
V3 has an RS pattern with decrease in R.
V4 to V6 have qRs patterns with decrease in q and R.
T is upright in all leads and is decreased in V5 and V6.
There has been some clockwise rotation of the heart.

C: Expiration.

The patterns are identical with the control series. There is slight increase in R and T in V5 and V6.
There has been slight counter-clockwise rotation of the heart.

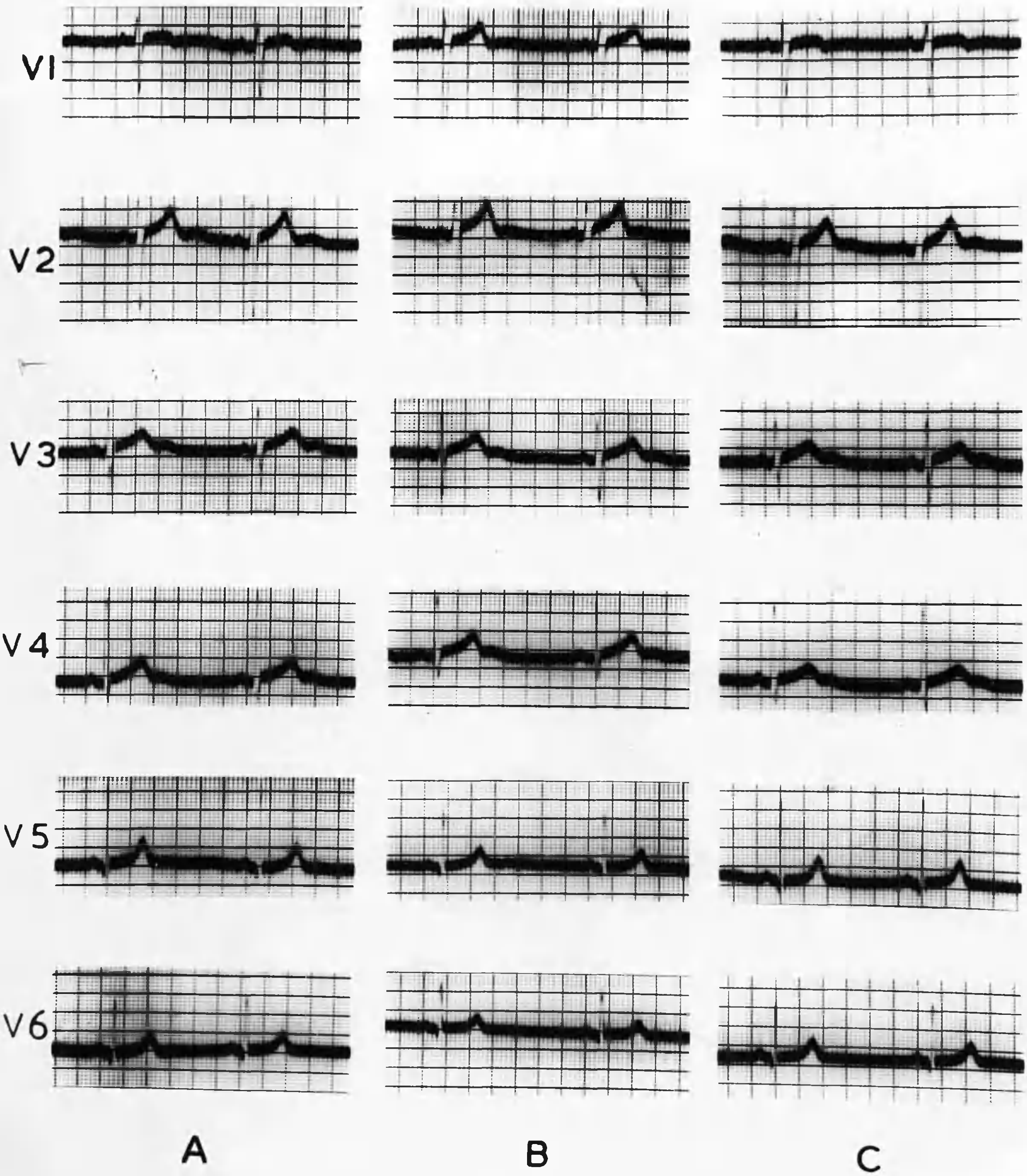
SUMMARY.

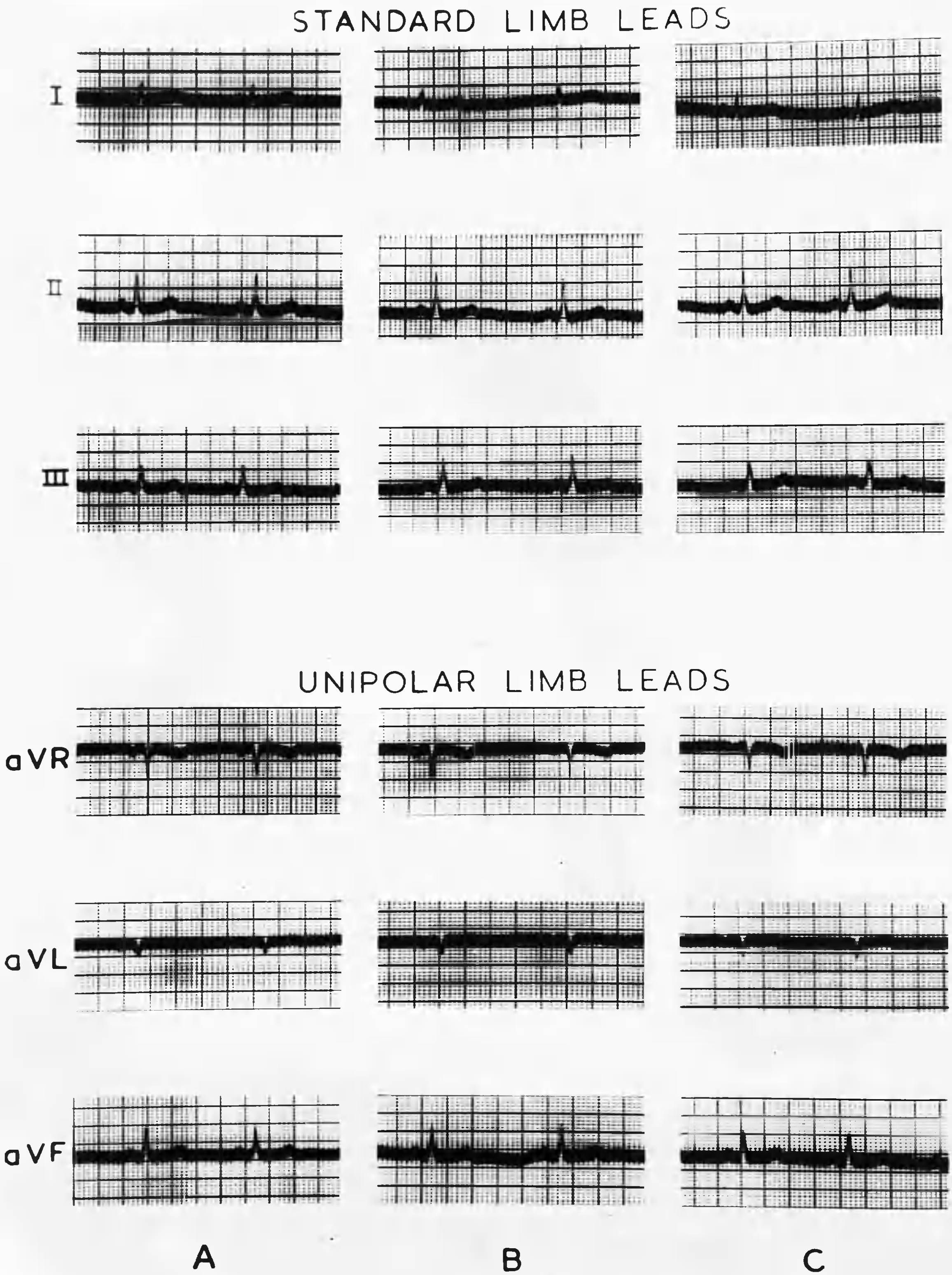
This is a normal horizontal heart with moderate counter-clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes less horizontal and undergoes clockwise rotation with backward rotation of the apex.

On expiration the heart becomes more horizontal and undergoes slight counter-clockwise rotation.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. I5 PLATE I05a

NORMAL. A. McL.

Age I7 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.

Lead I has a qRs pattern; lead II has an R pattern; lead III has an R pattern.

B: Inspiration.

The basic patterns are unaltered but lead I shows slight reduction in P,R and T; lead II shows increase in R; lead III shows increase in R and slight reduction in T.

There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are similar to the control series but lead I shows slight increase in R; lead II shows increase in R ; lead III shows slight decrease in R.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has slightly inverted P and flat T waves and a qrs pattern.

aVF has upright P and T waves and an R pattern.

The position of the heart is difficult to determine but it is probably horizontal.

B: Inspiration.

aVR remains unchanged.

aVL shows a qs pattern.

aVF remains unchanged.

C: Expiration.

aVR is unchanged.

aVL shows low upright T waves.

aVF shows slight decrease in R.

PLATE IO5b

PRECORDIAL LEADS.

A: Control.

VI and V2 have rS patterns.
V3 and V4 have RS patterns.
V5 and V6 have qRs patterns.
P and T are upright in all leads.

B: Inspiration.

VI to V3 have rS patterns with reduction in r.
V4 has an RS pattern.
V5 has an qRs pattern with reduction in R.
V6 is unaltered.
There has been clockwise rotation.

C: Expiration.

The patterns are identical with the control series apart from slight reduction of R and s in V5.

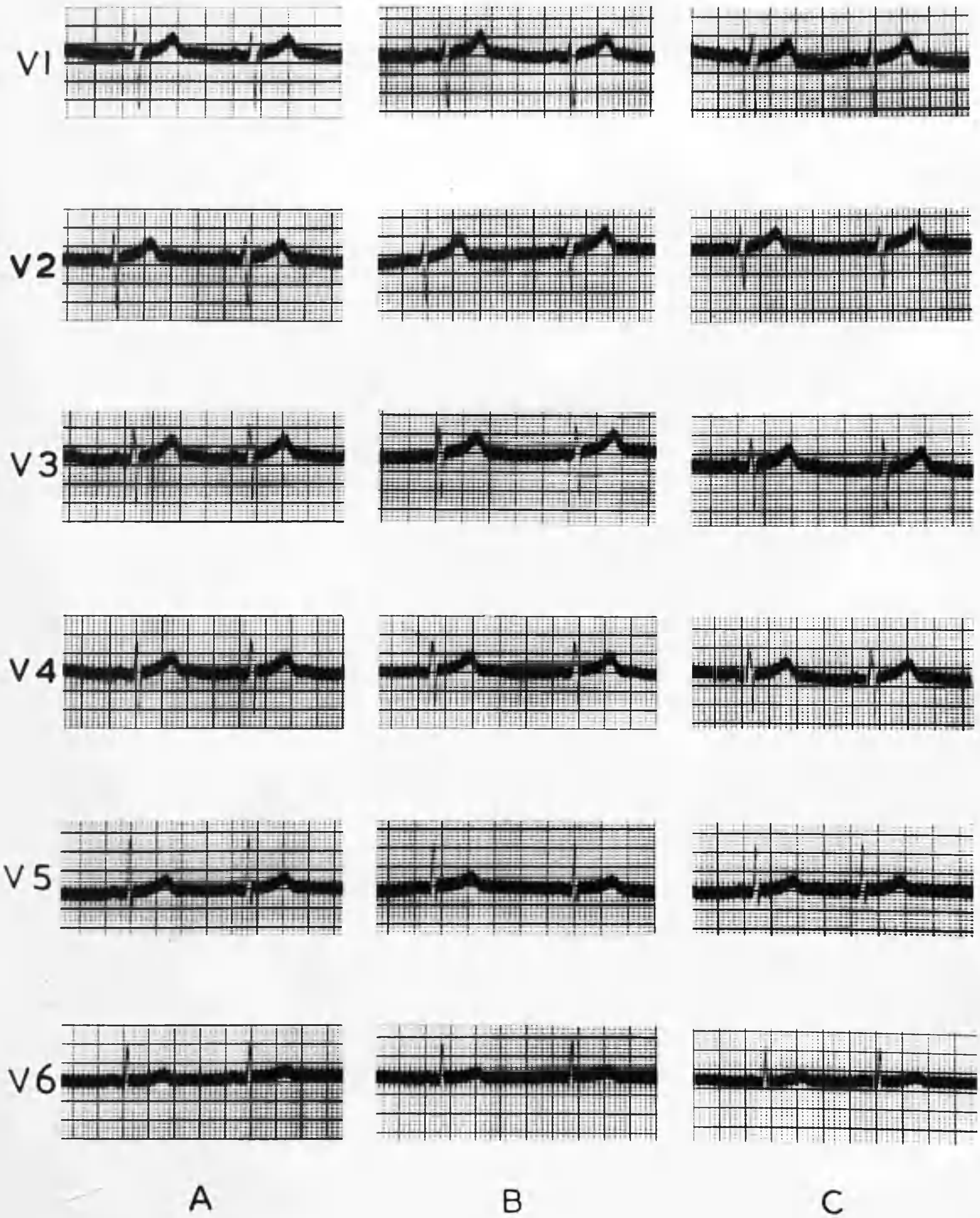
SUMMARY.

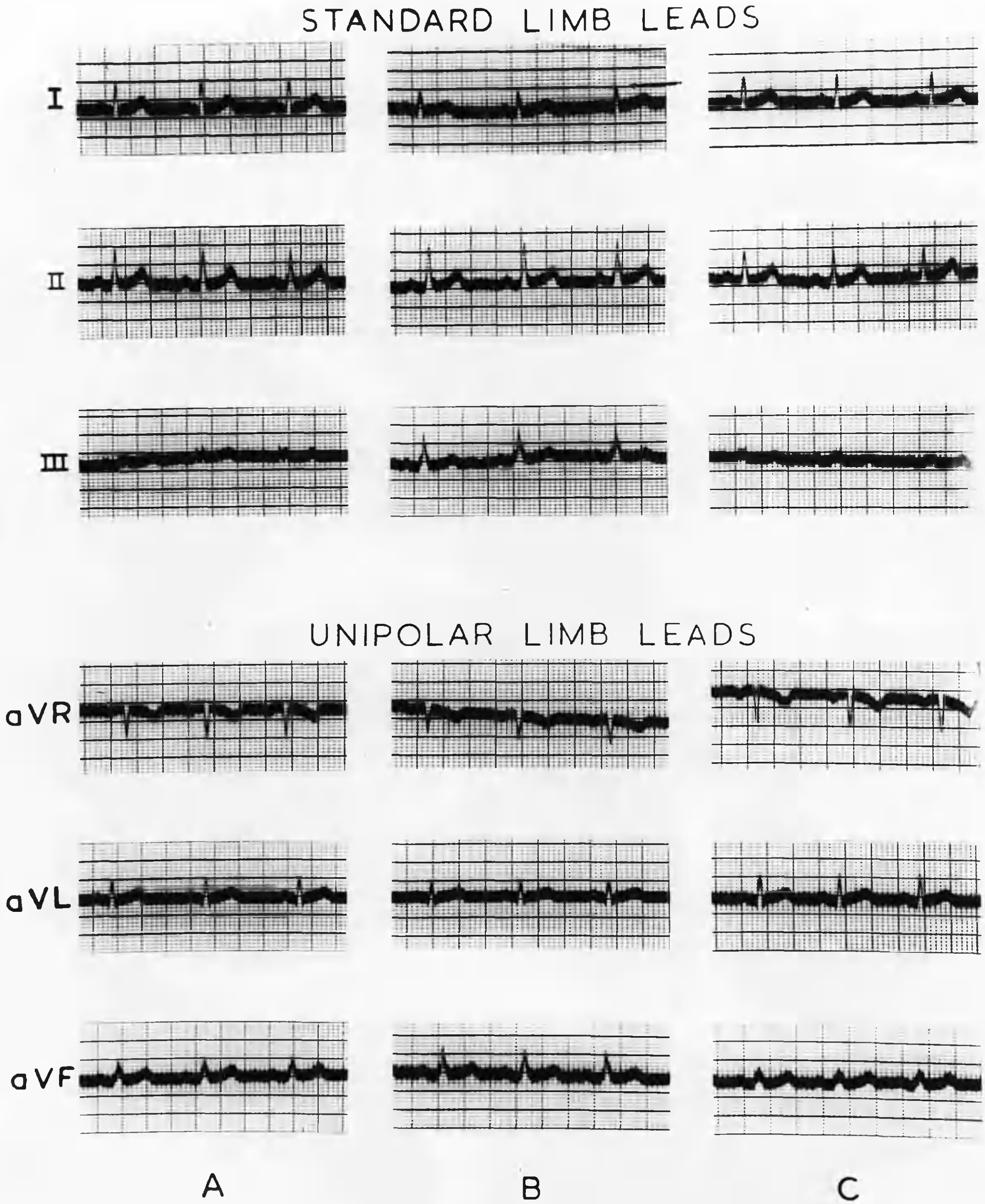
This is a normal horizontal heart with moderate clockwise rotation.

On inspiration the heart undergoes clockwise rotation and may become slightly more vertical.

On expiration there is no significant change.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.16 PLATE 106a

NORMAL.

A.R.

Age 18 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has a qRs pattern.
Lead II has an R pattern.
Lead III has a small vibratory qrs pattern.
All have upright P and T waves.
There is a tendency to left axis deviation.

B: Inspiration.

Lead I shows a decrease in all waves.
Lead II shows an increase in R and decrease in T.
Lead III shows a splintered R pattern.
There has been a shift of the QRS axis to the right.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.
aVL has a qRs pattern and upright P and T waves. It faces the epicardial surface of the left ventricle.
aVF has upright P and T waves and a splintered R pattern. It faces the epicardial surface of the right ventricle.
The heart is semi-horizontal.

B: Inspiration.

The basic patterns are unaltered.
aVR shows smaller P,S and T.
aVL shows smaller P,R and T.
aVF shows taller R and smaller T.
The heart has become less horizontal.

C: Expiration.

The basic patterns are unaltered.
aVR shows deeper P,S and T.
aVL shows taller P,R and T.
aVF shows smaller R and taller T.
The heart has become more horizontal.

PLATE IO6b

PRECORDIAL LEADS.

A: Control.

VI has an rS pattern.
V2 has an RS pattern.
V3, V4 and V5 have Rs patterns.
V6 has a qR pattern.
VI has diphasic P and upright T waves.
All other leads have upright P and T waves.
T is maximum in V2.

B: Inspiration.

The basic patterns are similar to the control series but R is smaller in V3 and V4 and taller in V6.
T is maximum in V2 and V3.
There has been slight clockwise rotation.

C: Expiration.

The patterns are similar to those of the control series but S is smaller in V3 and V4 and R smaller in V5 and V6.
T is maximum in V2.
There has been slight counter-clockwise rotation.

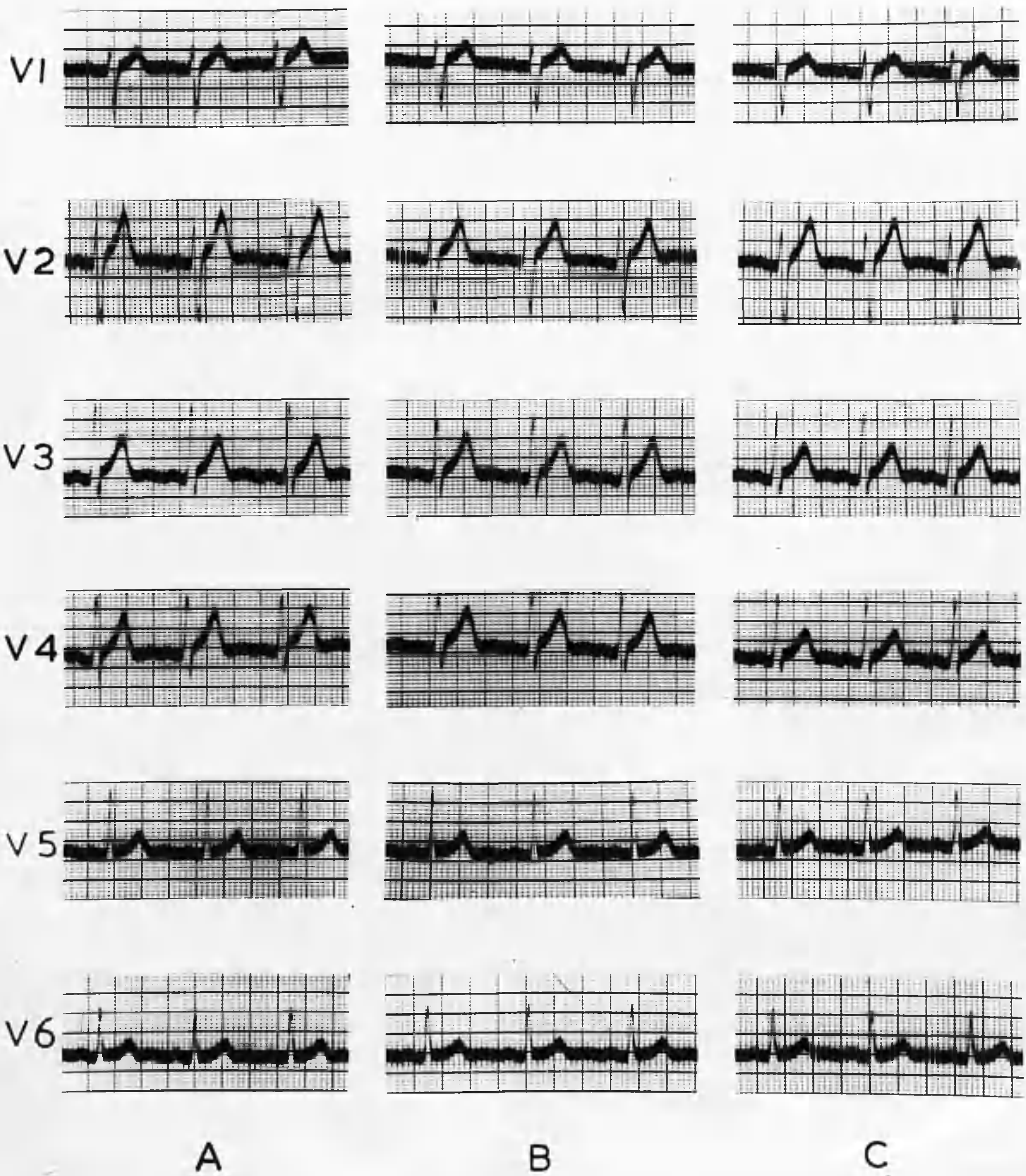
SUMMARY.

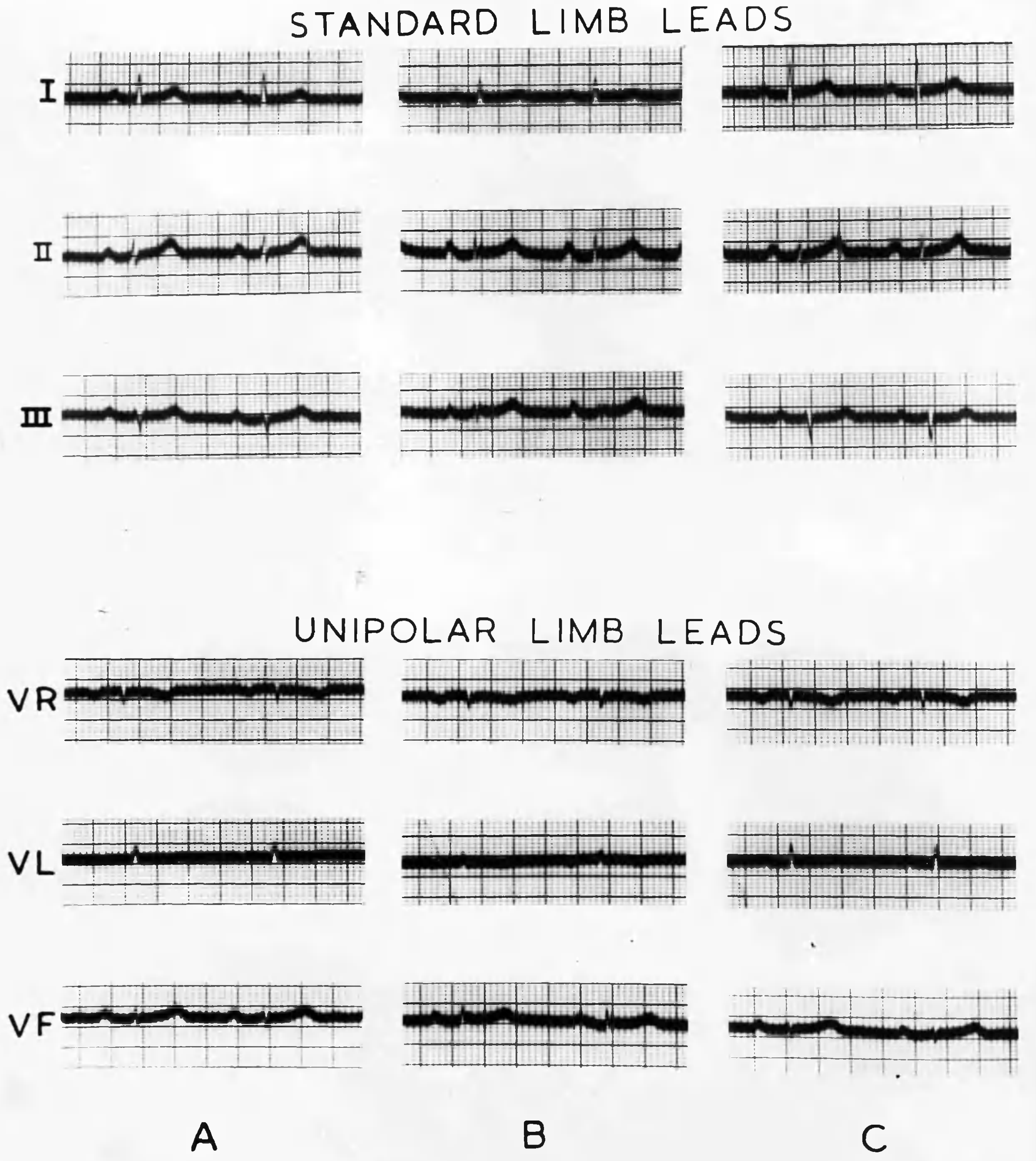
This is a normal semi-horizontal heart with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes less horizontal and undergoes slight clockwise rotation.

On expiration the reverse changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
VR
VL
VF
A
B
C

CASE NO. 17 PLATE 107a

NORMAL. G.R.

Age 32 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.
Lead I has a qRs pattern.
Lead II has an Rs pattern.
Lead III has an rS pattern.
There is left axis deviation.

B: Inspiration.

Lead I has a qR pattern with reduction in R; P and T are also reduced.

Lead II has an Rsr' pattern with reduction in s; P is increased.

Lead III has an rsr' pattern; P and T are increased.

There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are similar to the control series but lead I shows increase in R and T; lead II shows decrease in R; lead III shows increase in S and decrease in T.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

VR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VL has shallow inverted P and flat T waves and a qR pattern. It tends to face the back of the heart.

VF has upright P and T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal with backward rotation of the apex.

B: Inspiration.

VR shows a decrease in QS and T.

VL shows inverted P and T waves and a qr pattern. It now faces the back of the heart.

VF shows an Rs pattern.

The heart has become less horizontal.

C: Expiration.

VR shows deeper P, QS and T.

VL shows low upright P and T waves and a qR pattern with increase in R. It now faces the epicardial surface of the left ventricle.

V1 shows an rs pattern.
P and T are reduced.
The heart has become more horizontal.

PRECORDIAL LEADS.

A: Control.

V1 to V3 have rS patterns.
V4 has an RS pattern.
V5 has a qRs pattern.
V6 has a qR pattern.
P and T are upright in all leads.

B: Inspiration.

V1 to V3 have rS patterns with reduction in r.
V4 has an RS pattern with reduction in R and increase in S.
V5 has an Rs pattern with reduction in R and increase in s.
V6 has a qRs pattern with reduction in R.
T is reduced in V2 to V5.
There has been considerable clockwise rotation.

C: Expiration.

V1 to V3 have rS patterns with increase in r.
V4 has an RS pattern with increase in R and decrease in S.
V5 has a qRs pattern with increase in R.
V6 has a qR pattern with increase in R.
There has been counter-clockwise rotation.

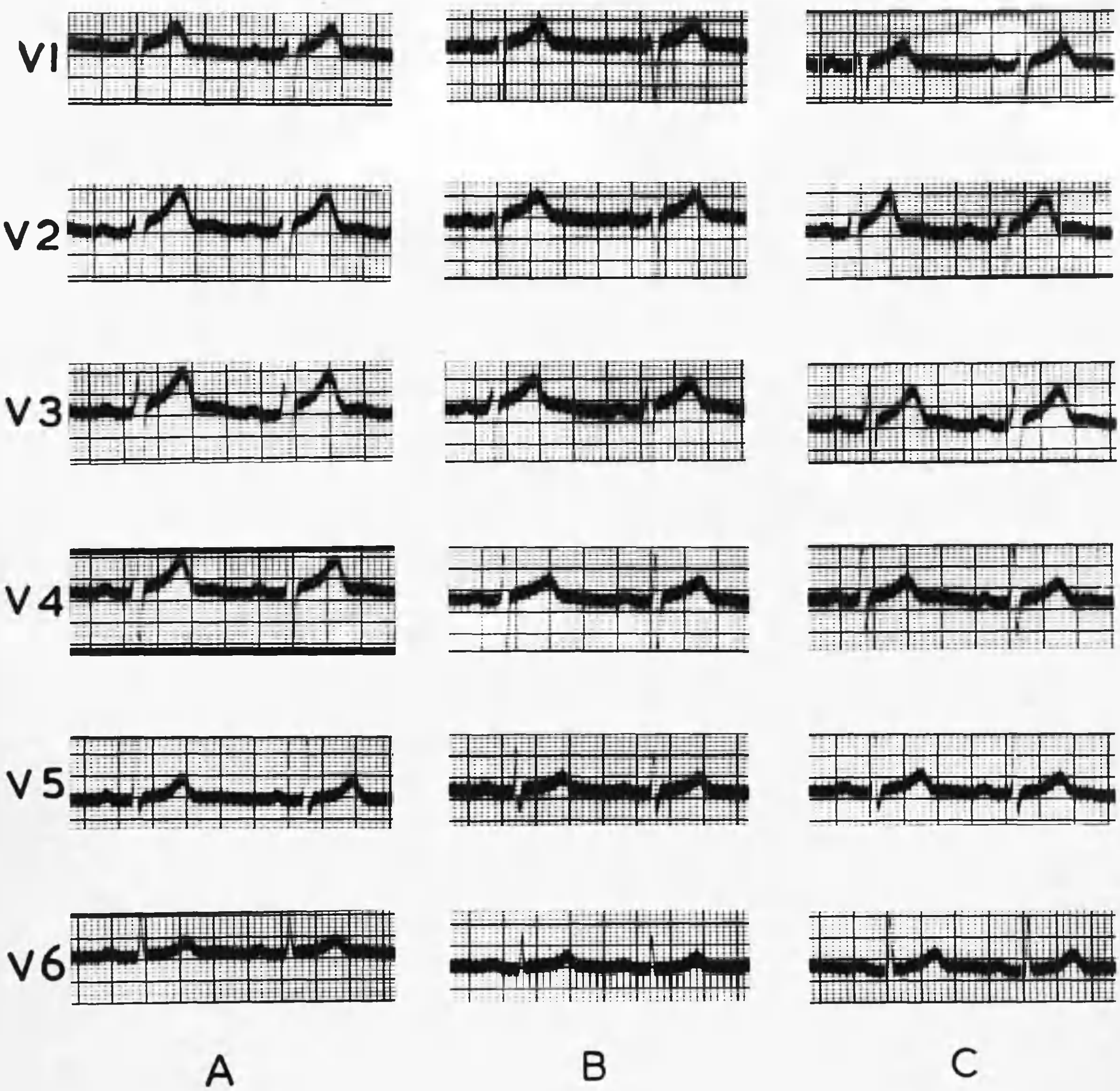
SUMMARY.

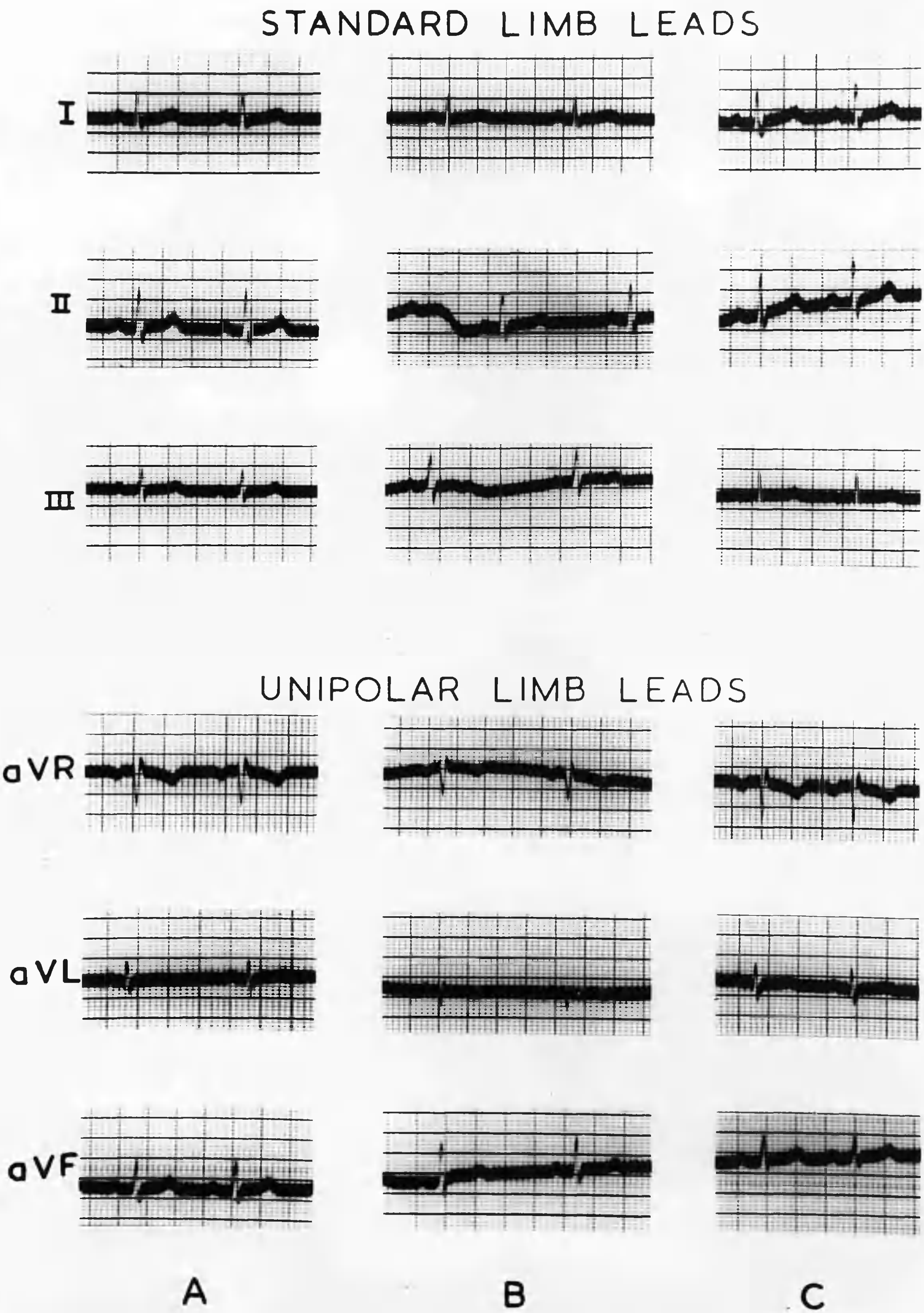
This is a normal horizontal heart with moderate clockwise rotation and slight backward rotation of the apex.

On inspiration the heart becomes less horizontal and undergoes further clockwise rotation and backward rotation of the apex.

On expiration the reverse changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.18 PLATE 108a

NORMAL. W.R.

Age 15 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves. Lead I has a qRs pattern; leads II and III have an Rs pattern.

There is no axis deviation.

B: Inspiration.

Lead I shows decrease in R,s and T.

Lead II shows decrease in R and T.

Lead III shows increase in R and s; T is decreased.

There has been a slight shift of the QRS axis to the right.

C: Expiration.

Lead I shows an increase in R,s and T.

Lead II is unaltered.

Lead III shows a qRs pattern with reduction in s; T is decreased.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.

aVL has low upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

aVF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is semi-horizontal.

B: Inspiration.

aVR has a Qr pattern; P and T are less inverted.

aVL has an rSr' pattern; P is diphasic and T is slightly inverted.

aVF has a qRs pattern; T is smaller.

The heart has become vertical and has rotated clockwise so that aVR now faces the back of the heart.

C: Expiration.

The patterns are similar to the control series, but R and T are slightly taller in aVL and slightly smaller in aVF.

The heart has become more horizontal.

PLATE I08b

PRECORDIAL LEADS.

A: Control.

Leads VI and V2 have rS patterns.
Leads V3 to V6 have RS patterns.
All have upright P and T waves.

B: Inspiration.

Leads VI to V3 have rS patterns.
Leads V4 to V6 have RS patterns with deeper S waves.
The T waves are taller throughout.
There has been some clockwise rotation.

C: Expiration.

The patterns are similar to those of the control series but the S waves are slightly smaller.

T is smaller throughout.

There has been some counter-clockwise rotation.

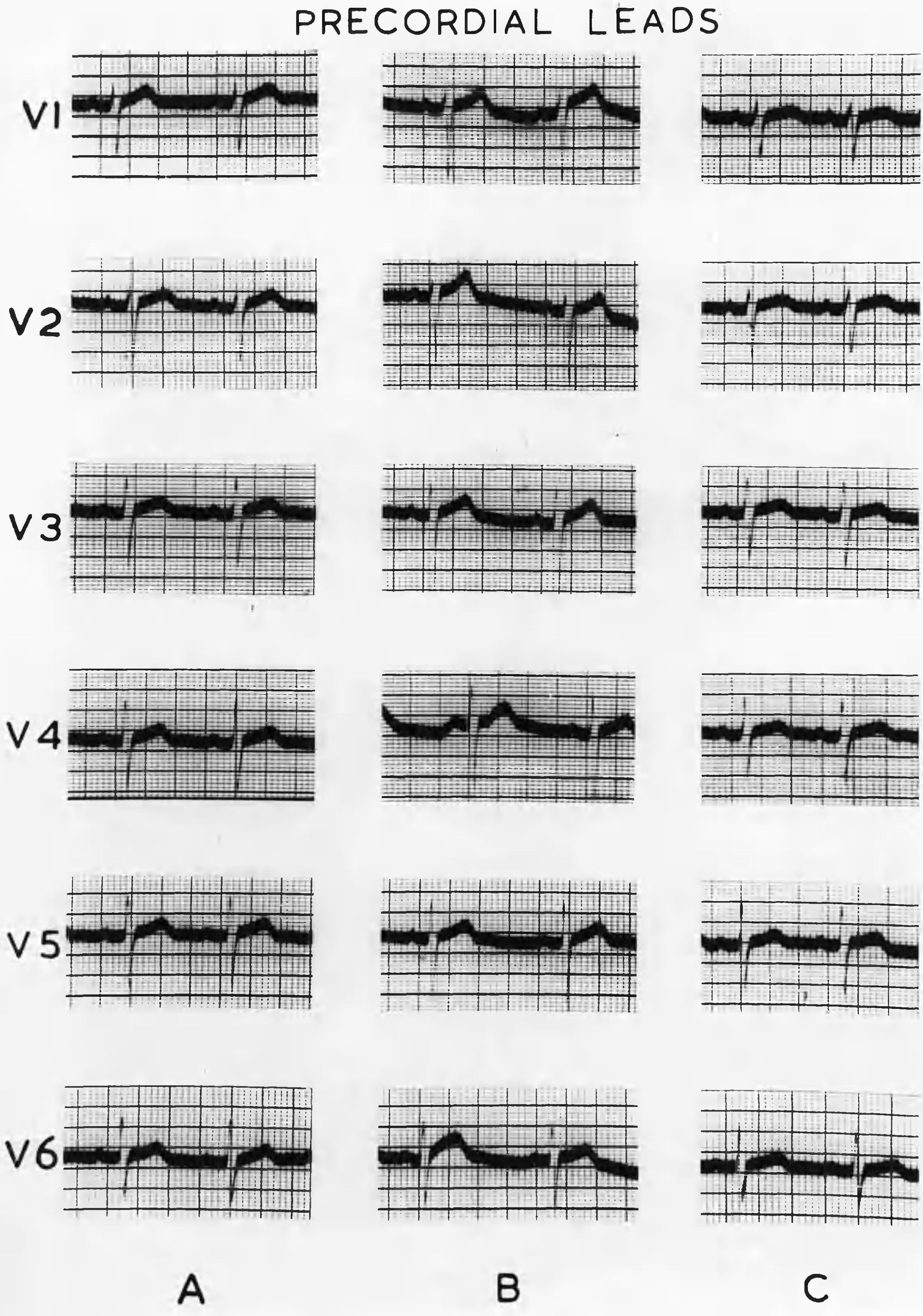
The decrease in the T waves is probably due to the main muscle mass of the heart moving upwards away from the precordial leads as the heart becomes more horizontal. The reverse process would explain the increase in height of the T waves in inspiration.

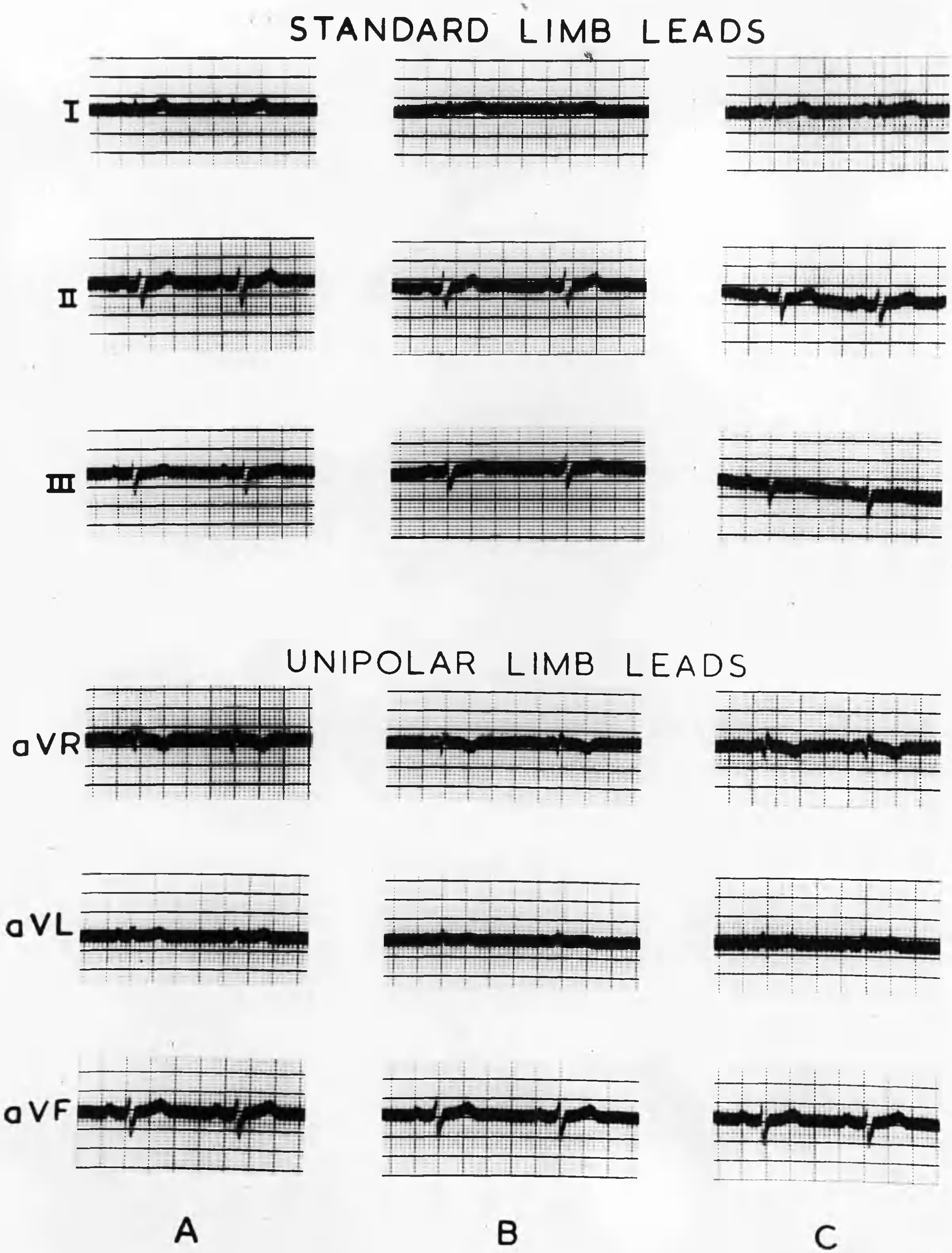
SUMMARY.

This is a normal semi-horizontal heart with marked clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes vertical and undergoes clockwise rotation round its long axis.

On expiration it becomes more horizontal and undergoes counter-clockwise rotation.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.I9 PLATE I09a

NORMAL.

W.A.

Age 33 years.

STANDARD LIMB LEADS.

A: Control.

All leads have upright P and T waves.

Lead I has a small Rs pattern; lead II has an RS pattern; lead III has an rS pattern.

B: Inspiration.

The basic patterns are unaltered but lead I shows a decrease in P,R and T while lead III shows an increase in r and a decrease in S.

There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are similar to the control series but lead I shows slight increase in R while lead III shows a decrease in r and slight increase in S.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QR pattern. It faces the back of the heart.

aVL has upright P and T waves and a small splintered qr pattern.

aVF has upright P and T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

The position of the heart is difficult to determine. It is probably semi-horizontal.

B: Inspiration.

The basic patterns are unaltered .

aVR shows less inversion of P and T and slight reduction of R.

aVL shows reduction in P and T .

C: Expiration.

All leads are practically identical with the control series but aVL shows a slight increase in r and aVF a decrease in R and increase in S.

The heart has become slightly more horizontal.

PLATE 109b

PRECORDIAL LEADS.

A: Control.

V1 to V3 have rS patterns.
V4 and V5 have RS patterns.
V6 has an Rs pattern.
P and T are upright in all leads.

B: Inspiration.

The patterns are similar to those in the control series but r and S are reduced in V2 and V3; R and S are reduced in V4; R is reduced in V5 and V6.

There has been clockwise rotation.

C: Expiration.

The patterns are similar to those of the control series but s is slightly larger in V6. This is due to the heart becoming more horizontal.

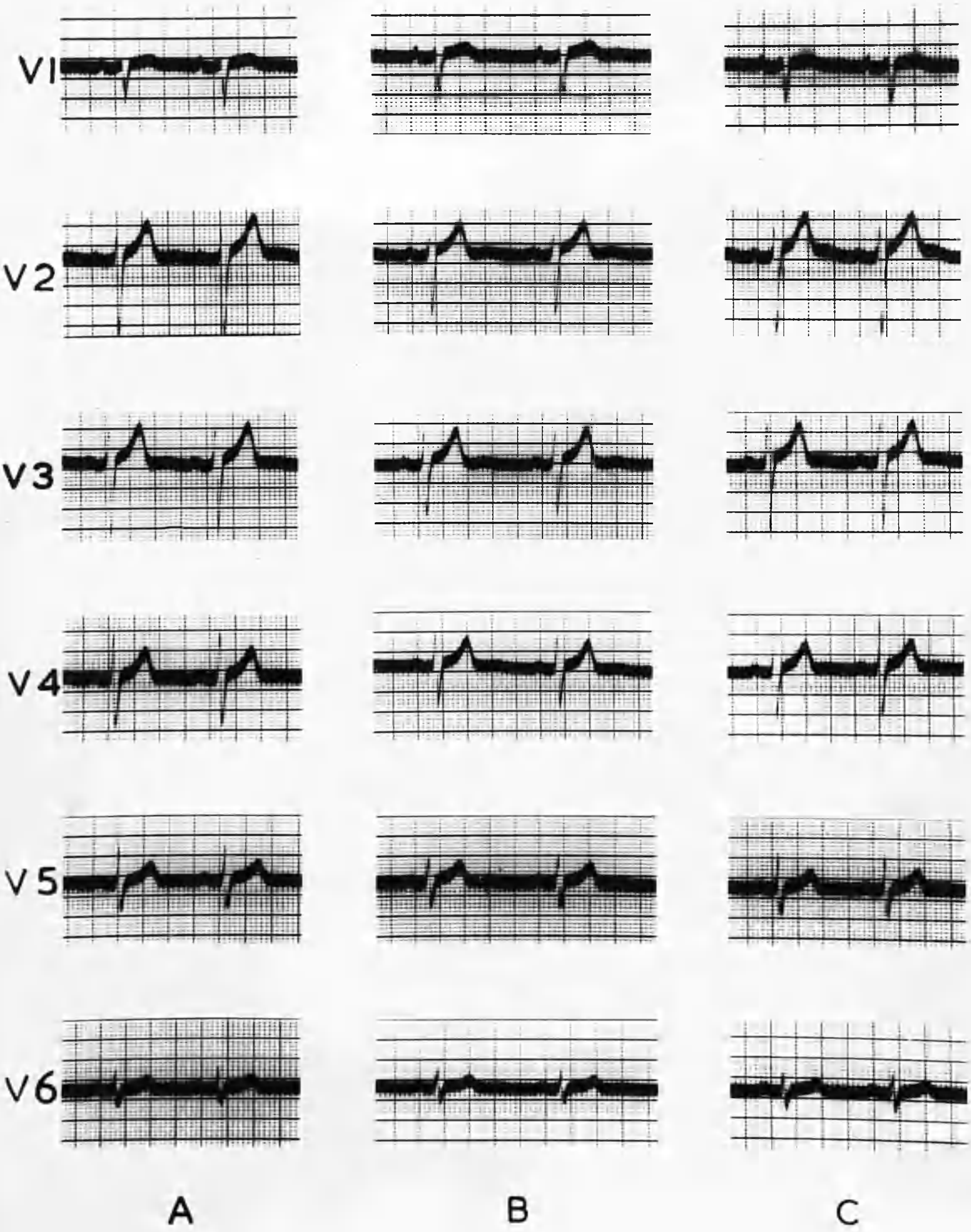
SUMMARY.

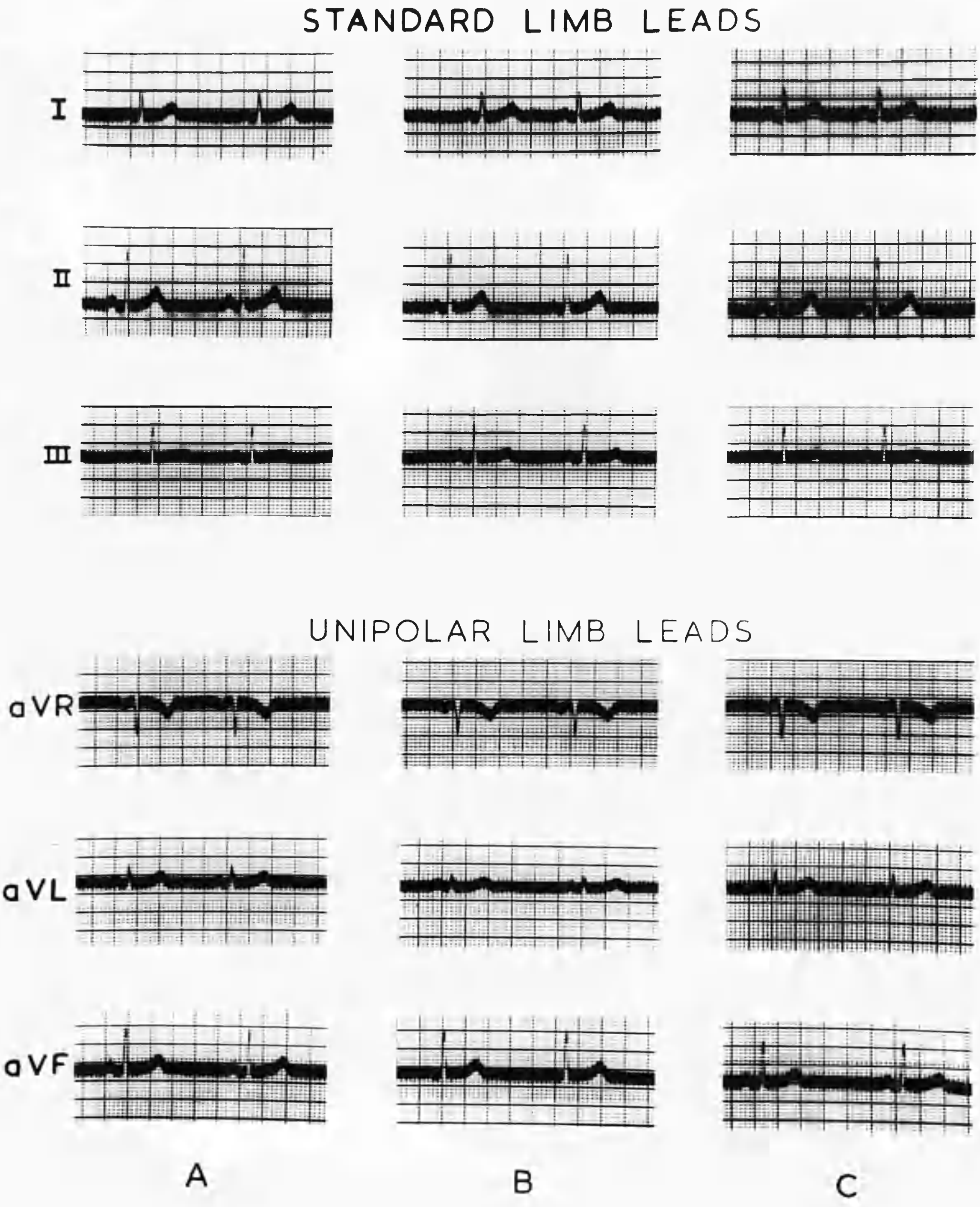
This is a normal semi-horizontal heart with marked clockwise rotation and probably forward rotation of the apex.

On inspiration the heart undergoes further clockwise rotation.

On expiration it becomes slightly more horizontal.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.20 PLATE II0a

NORMAL. Miss M.H.

Age 17 years.

STANDARD LIMB LEADS.

A: Control.
All leads have upright P and T waves and R patterns.
There is no axis deviation.

B: Inspiration.
The patterns are very similar to the control series.
Lead I shows slight reduction in R and lead III shows slight increase in R and T.

C: Expiration.
The patterns are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.
aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.
aVL has upright P and T waves and an R pattern.
aVF has upright P and T waves and a taller R pattern.
The heart is in the intermediate position.

B: Inspiration.
The patterns are identical with the control series, but aVR shows a smaller QS and a less inverted T; aVL shows smaller R and T.
The heart may have become slightly vertical.

C: Expiration.
All leads are identical with the control series.

PRECORDIAL LEADS.

A: Control.

VI has an rS pattern.
V2 and V3 have RS patterns.
V4,V5 and V6 have Rs patterns.
P and T are upright in all leads.

B: Inspiration.

The patterns are identical with the control series apart from slight increase in S in VI and slight reduction in R in V4 to V6.

There has been little or no rotation of the heart.

C: Expiration.

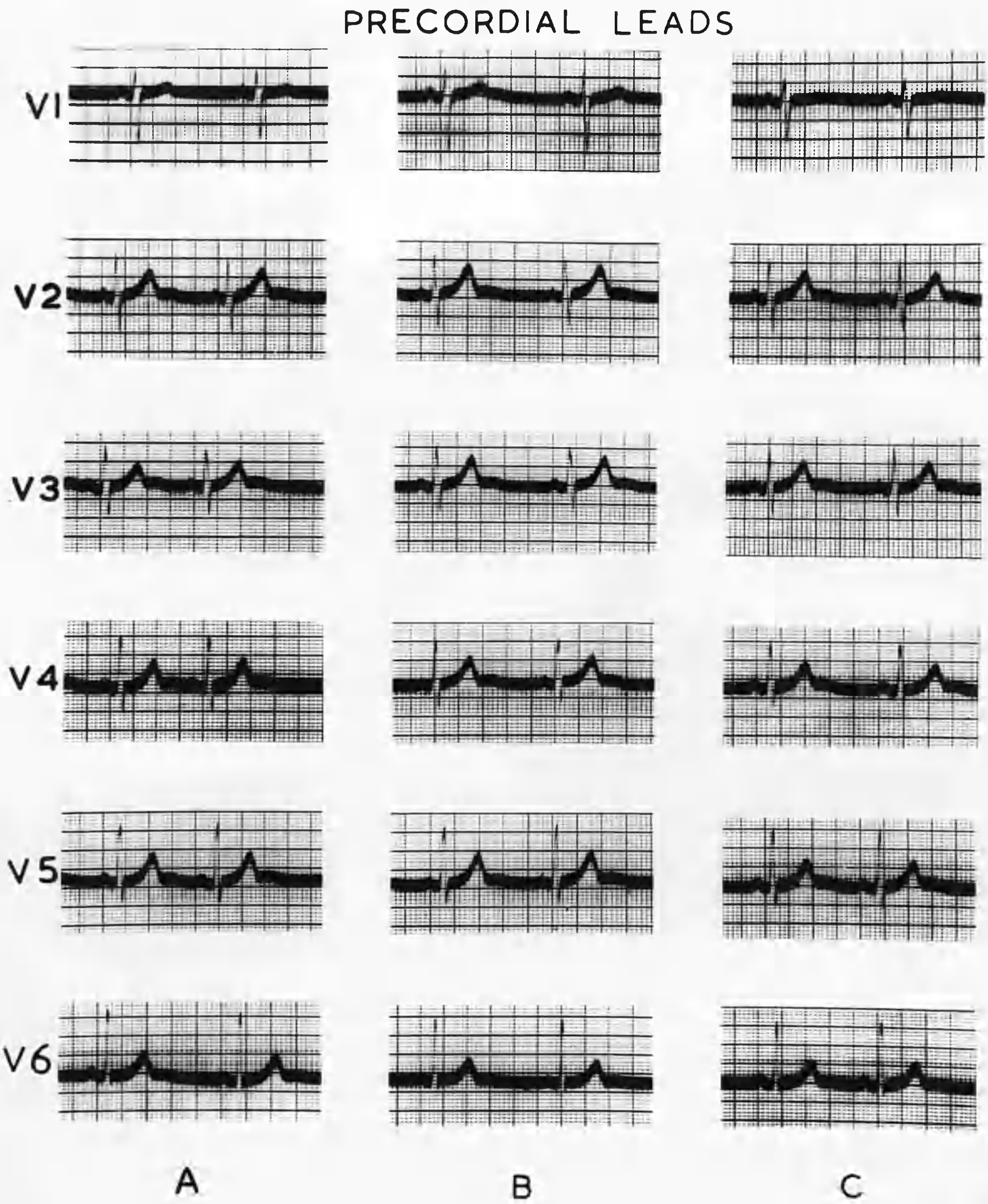
The patterns are identical with the control series apart from slight reduction of S in VI, V2 and V3 and of s in V4.

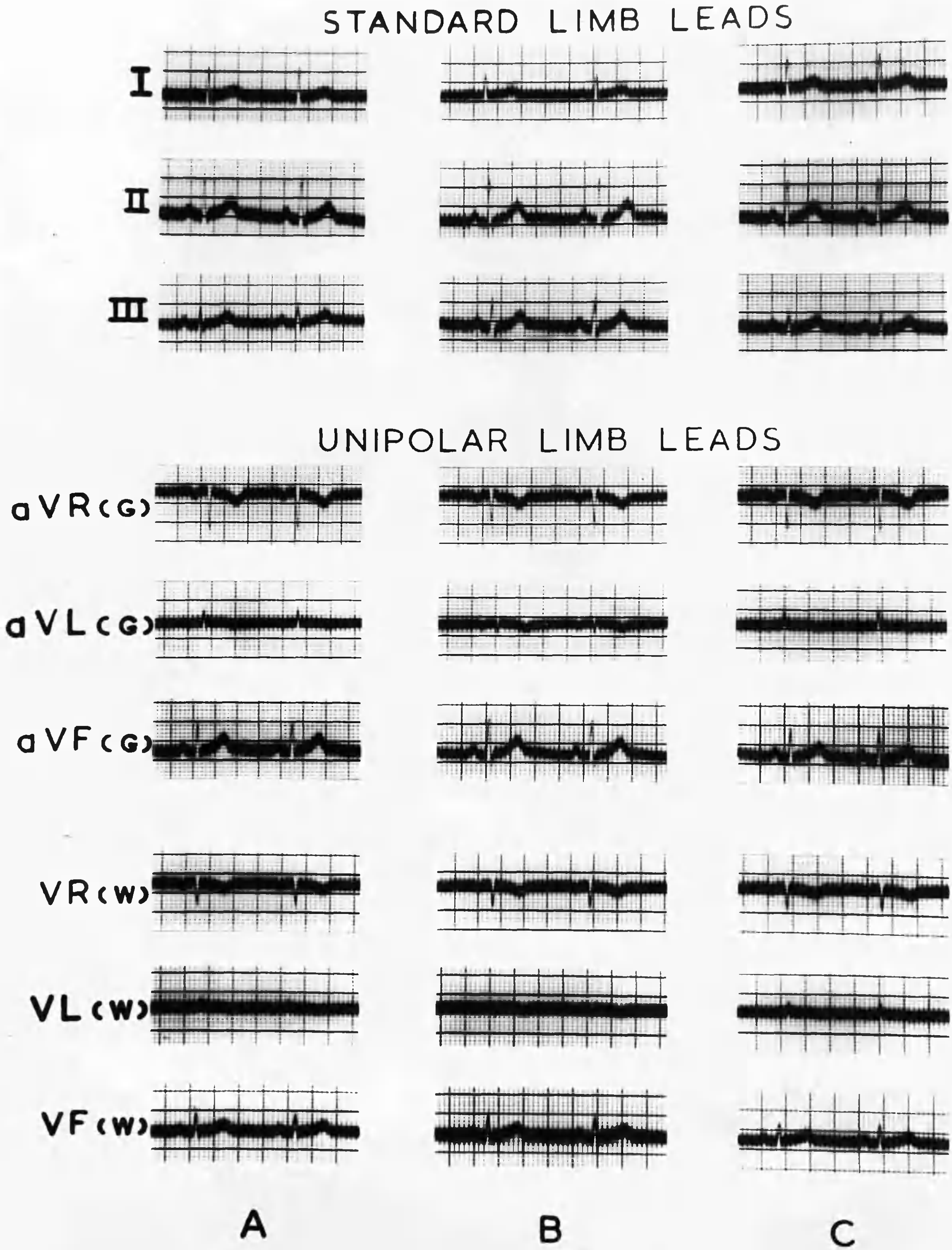
There has been very slight counter-clockwise rotation.

SUMMARY.

This is a normal heart probably in an intermediate position with marked clockwise rotation.

There are no conspicuous changes with either inspiration or expiration.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
A
B
C

CASE NO.21 | PLATE IIIa

ABNORMAL. | J.W.

Diagnosis: Neurocirculatory Asthenia. | Age 33 years.

STANDARD LIMB LEADS.

A: Control.
All leads have upright P and T waves and a qRs pattern.

B: Inspiration.
Lead I shows reduction in P,R and T.
Lead II shows slight increase in R and s.
Lead III shows increase in R,s and T.
There has been a shift of the QRS axis to the right.

C: Expiration.
Lead I shows an increase in R.
Lead II shows a decrease in R and T.
Lead III shows a decrease in R and T.
There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.
aVR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.
aVL has shallow inverted P and T waves and an Rsr' pattern. It faces the epicardial surface of the right ventricle.
aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.
The heart is vertical with forward rotation of the apex.

B: Inspiration.
aVR still shows an rSr' pattern with reduction in S and increase in r'; P and T are less inverted.
aVL has an rSr' pattern; P and T are more deeply inverted.
aVF has an Rs pattern with increase in R and s; T is increased.
The heart has become more vertical.

C: Expiration.
aVR is unaltered.
aVL shows an Rsr' pattern with increase in R and decrease in s; T is flat.

aVF shows a qRs pattern with decrease in R; T is reduced.

The heart has become less vertical.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PRECORDIAL LEADS.

A: Control.

V1 has an rS pattern.
V2 has an RS pattern.
V3 has an Rs pattern.
V4 to V6 have qRs patterns.
P and T are upright in all leads.

B: Inspiration.

V1 has an rSr' pattern, with decrease in S.
V2 has an rS pattern, with decrease in S.
V3 has an RS pattern, with decrease in R.
V4 has an Rs pattern, with decrease in R and increase in s.
V5 and V6 have qRs patterns with decrease in R and increase in s.
There has been clockwise rotation of the heart.

C: Expiration.

The patterns are similar to the control series but there is slight reduction of S in V2 and of s in V3 to V6.

There has been slight counter-clockwise rotation of the heart.

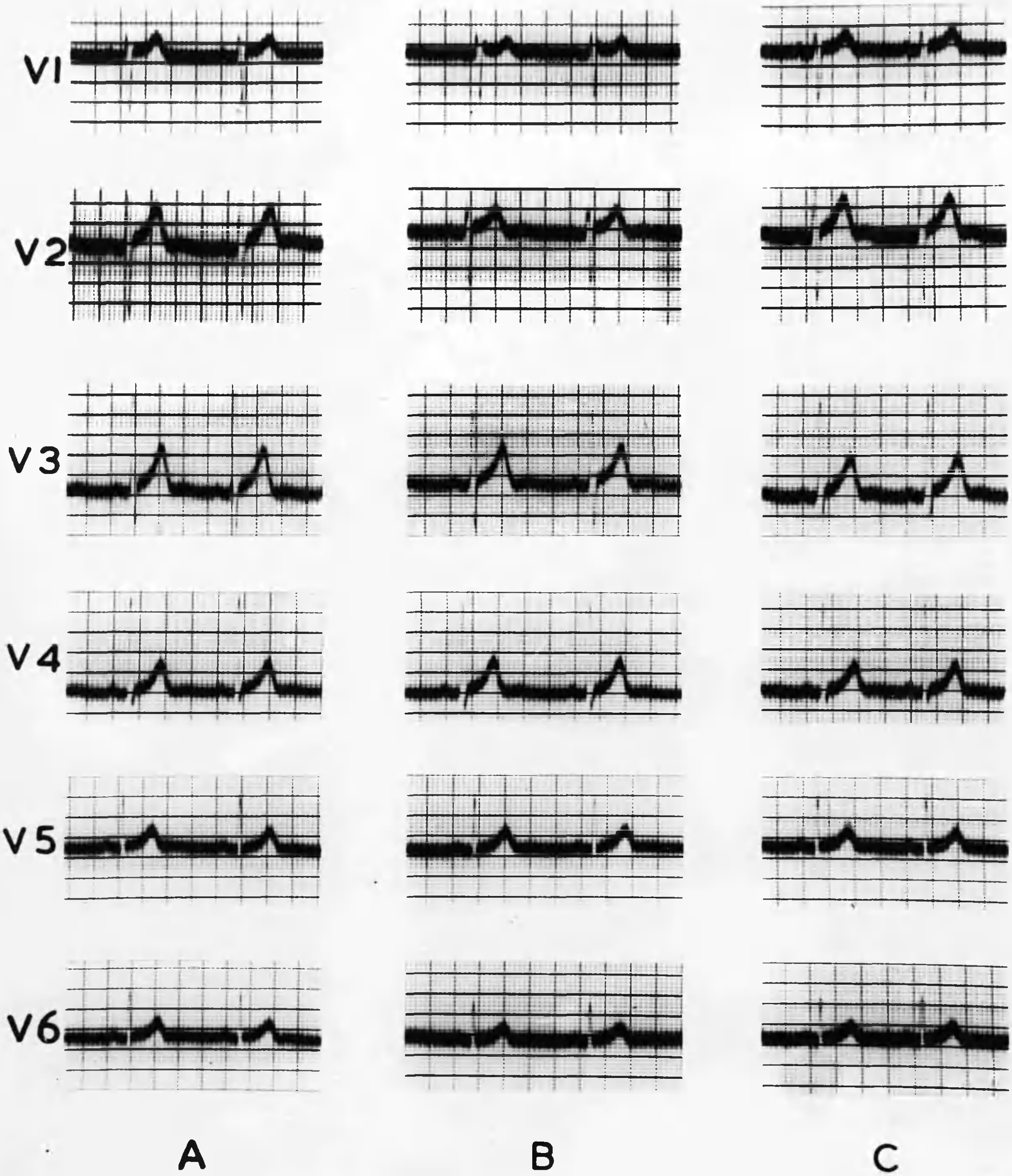
SUMMARY.

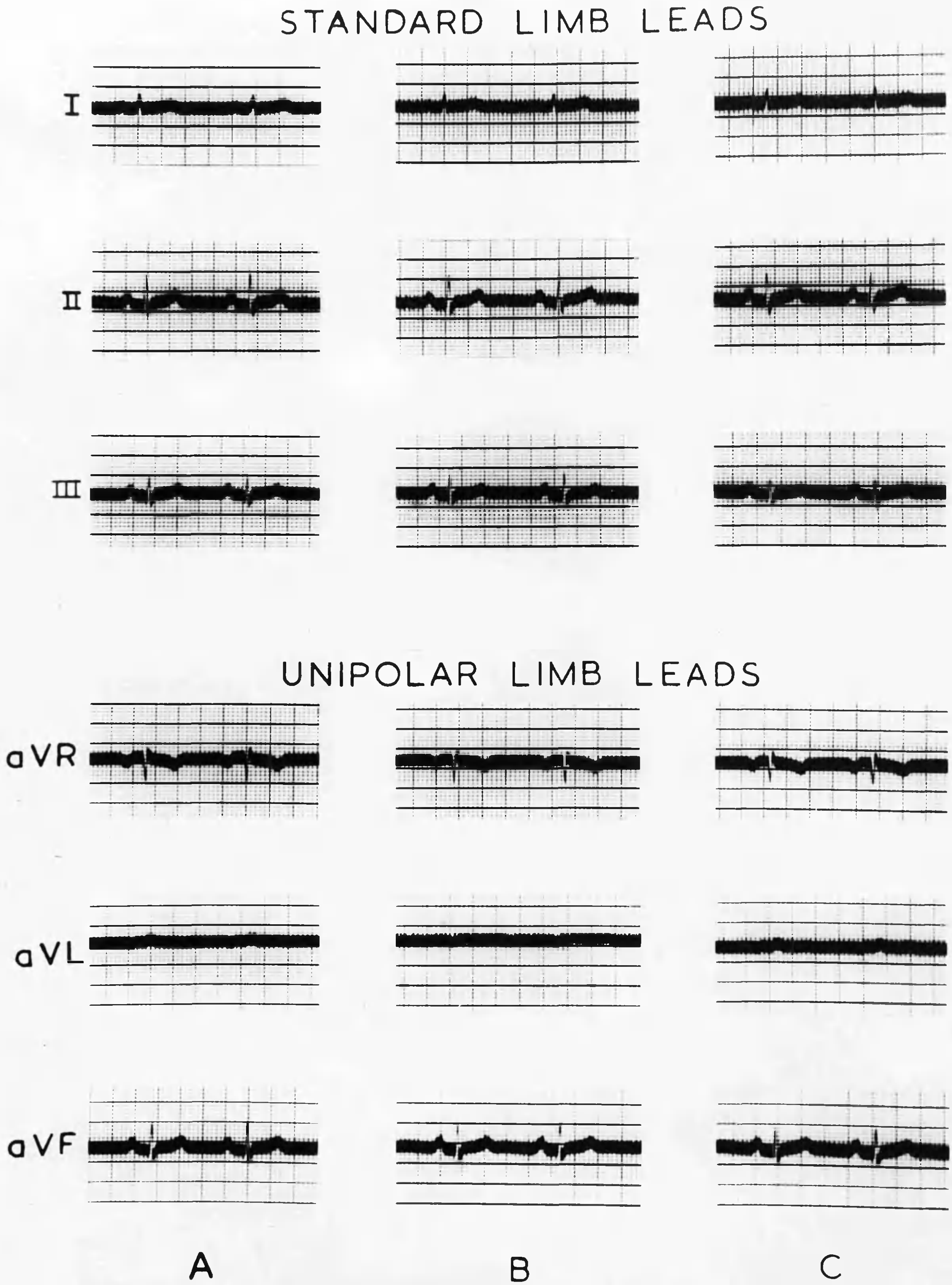
In this case the heart is vertical with moderate counter-clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation with some backward rotation of the apex.

On expiration the reverse changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

ABNORMAL. P.McK.

Diagnosis: Chronic Bronchitis and Emphysema. Age 49 years.

STANDARD LIMB LEADS.

A: Control

Lead I has upright P and T waves and a small Rs pattern.

Leads II and III have upright P and T waves and qRs patterns.

B: Inspiration.

Lead I has flat P waves and an Rs pattern with reduction in R.

Lead II is unchanged.

Lead III shows slight increase in R.

C: Expiration.

The patterns are similar to the control series but lead I has a taller R; lead II has smaller R and deeper s; lead III has smaller R and deeper s and smaller T.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

aVL has shallow inverted P and flat T waves and a small vibratory rsr' pattern. It probably faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR shows slightly smaller Q and less inverted T.

aVL has flat P and T waves and no distinguishable QRS complex.

aVF is unchanged.

There has been no significant alteration in the position of the heart.

C: Expiration.

aVR shows slight decrease in Q and increase in r.

aVL shows low upright T and small splintered r.

aVF shows slightly smaller R and deeper s.

The heart has become slightly less vertical.

PRECORDIAL LEADS.

A: Control

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qRs pattern.
P is diphasic in VI, but upright and bifid in all other leads.
T is upright in all leads.

B: Inspiration.

VI to V3 have rS patterns with decrease in r and increase in S in V3.
V4 and V5 have RS patterns with decrease in R.
V6 has an Rs pattern.
There has been slight clockwise rotation of the heart.

C: Expiration.

VI and V2 have rS patterns with increase in r.
V3 and V4 have RS patterns with increase in R.
V5 has an Rs pattern.
V6 has a qRs pattern with decrease in s.
There has been counter-clockwise rotation of the heart.

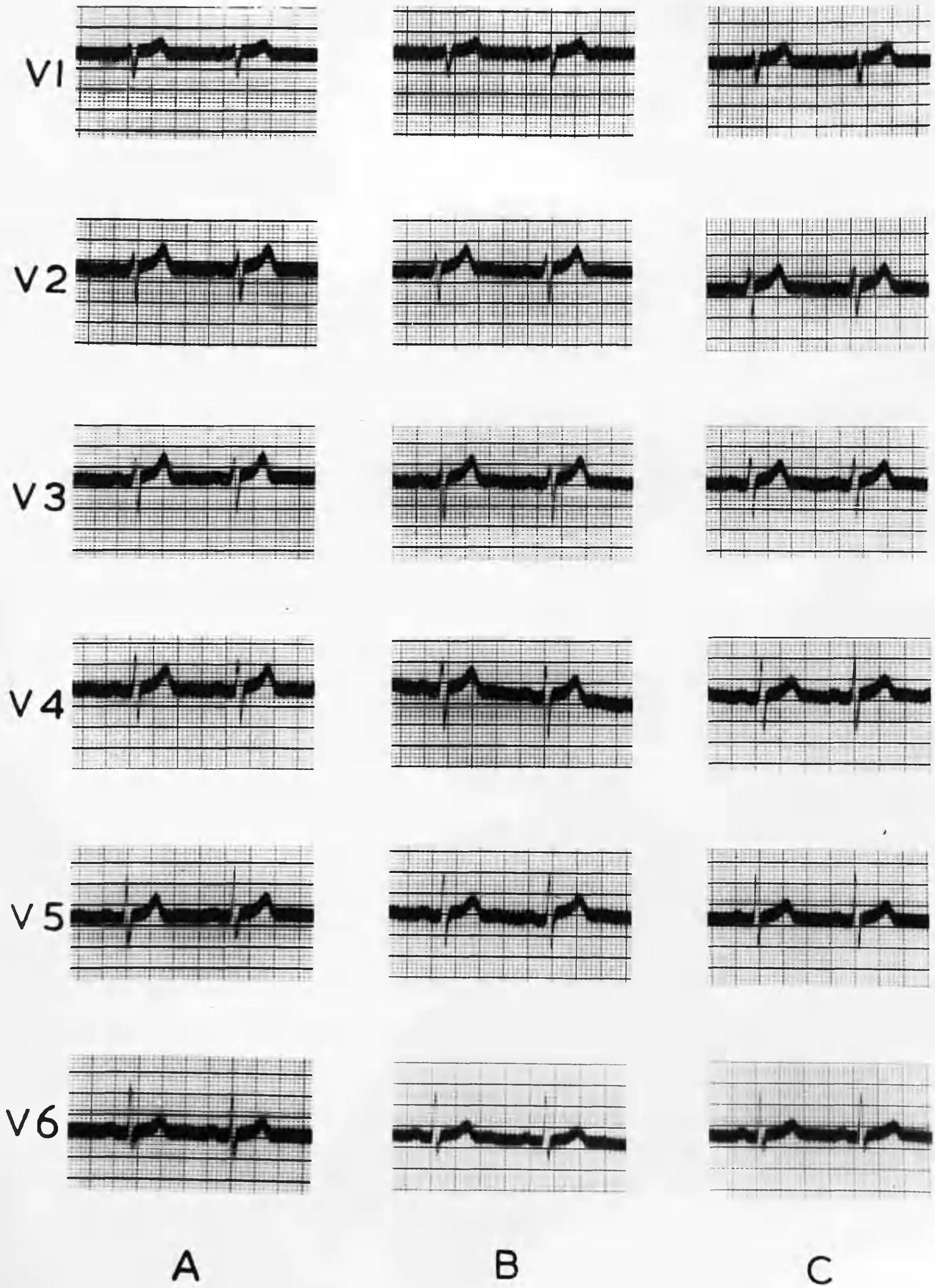
SUMMARY.

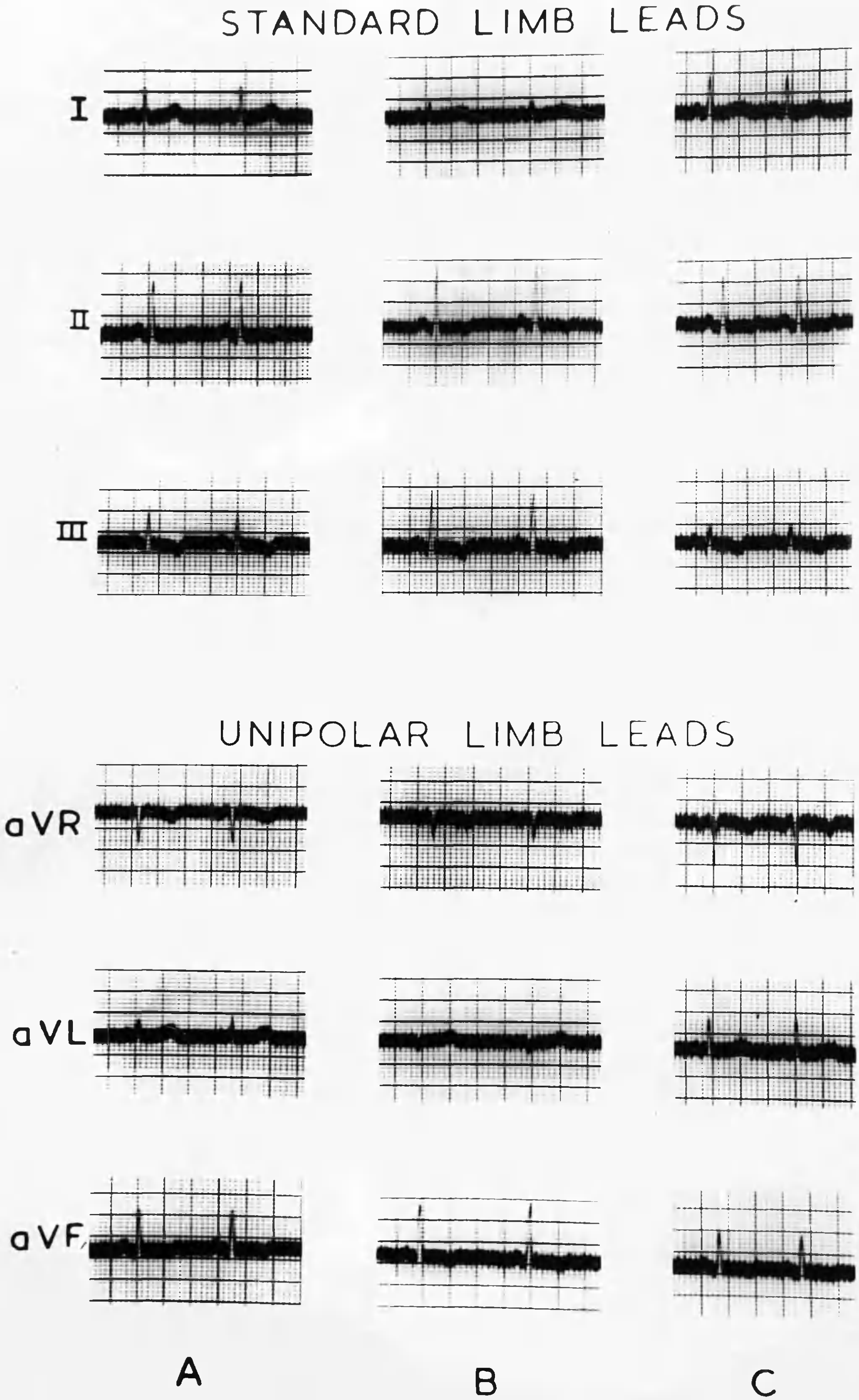
This is a vertical heart with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart undergoes slight clockwise rotation.

On expiration the heart undergoes counter-clockwise rotation and becomes slightly less vertical.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

ABNORMAL. Mrs. M.McK.

Diagnosis: Essential Hypertension. Age 30 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an R pattern.

Lead II has upright P and shallow diphasic T waves and a qR pattern.

Lead III has upright P and inverted T waves and a qR pattern.

B: Inspiration.

Lead I shows reduction in P,R and T.

Lead II shows slightly more diphasic T waves.

Lead III shows increase in R and slightly more inverted T waves.

There has been a shift of the QRS axis to the right.

C: Expiration.

Lead I shows increase in R.

Lead II is unaltered.

Lead III shows decrease in P; q is increased and R is decreased.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has an rsR' pattern and upright P and T waves. It faces the epicardial surface of the right ventricle.

aVF has upright P and shallow inverted T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is semi-vertical.

B: Inspiration.

aVR has less inverted P and T and a smaller QS pattern.

aVL has a qs pattern; P is flat and T is slightly reduced.

aVF shows increase in R; T is slightly more inverted.

The heart has become more vertical.

C: Expiration.

aVR shows more deeply inverted P and T waves and a deeper QS.

aVL has an R pattern.

aVF shows decrease in R and practically flat T waves.

The heart has become less vertical.

PRECORDIAL LEADS.

A: Control.

VI has an rS pattern.
V2 and V3 have RS patterns.
V4 has an Rs pattern.
V5 and V6 have qR patterns.
P and T are upright in all leads.

B: Inspiration.

VI to V3 have rS patterns.
V4 has an Rs pattern with increase in s.
V5 has a qRs pattern.
V6 has a qR pattern with reduction in q and R.
T is reduced in VI to V4 and increased in V5 and V6.

There has been clockwise rotation of the heart.

C: Expiration.

VI has an rS pattern.
V2 and V3 have RS patterns, with increase in R.
V4 to V6 have qR patterns.
T is decreased in all leads.

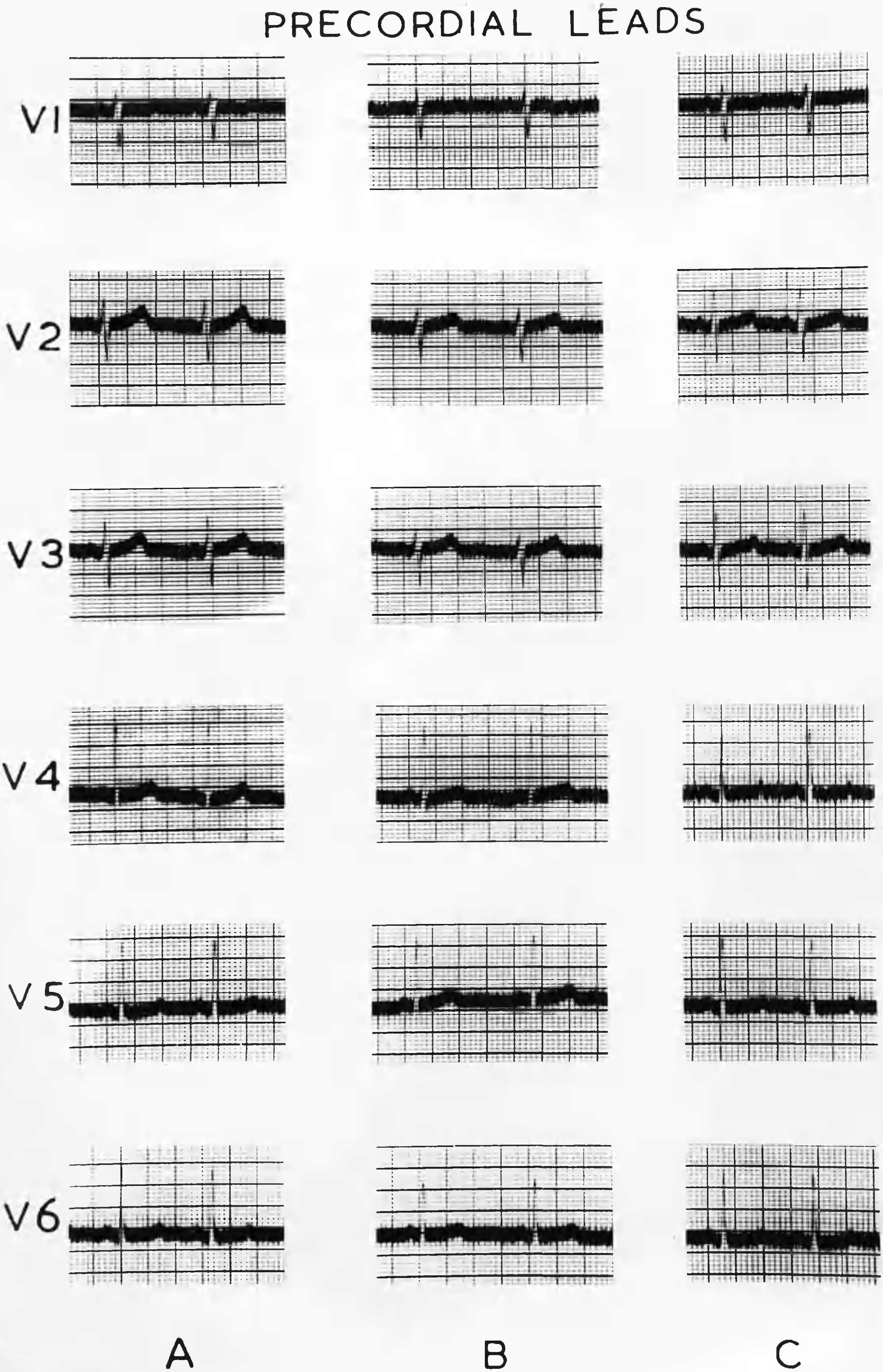
There has been counter-clockwise rotation of the heart.

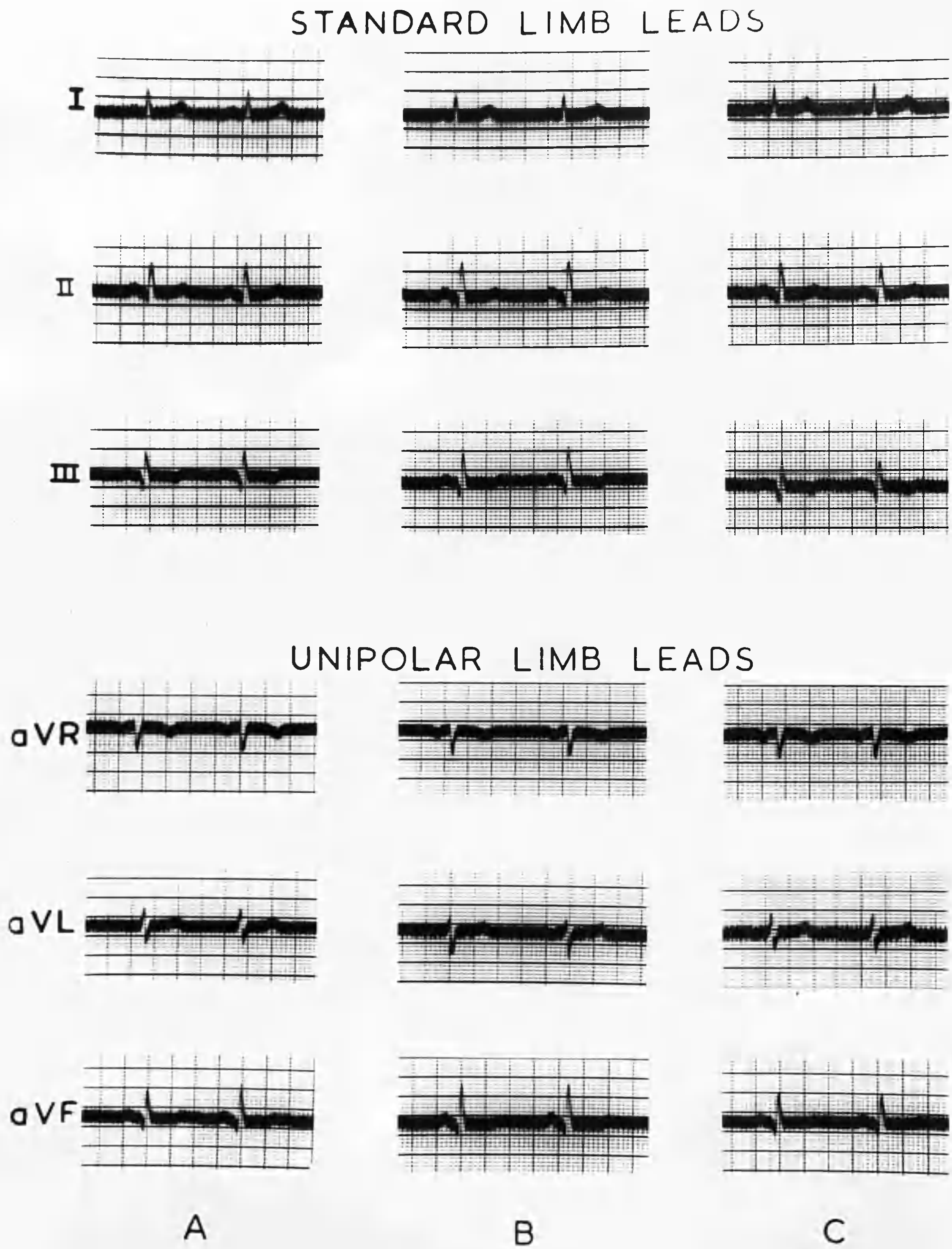
SUMMARY.

In this case the heart is semi-vertical with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation.

On expiration the reverse changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.24 PLATE II4a

ABNORMAL. R.K.

Diagnosis: Coronary Insufficiency. Age 66 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an R pattern.

Lead II has upright P and T waves and a qR pattern.

Lead III has upright P and shallow inverted T waves and a QR pattern. The RT segment is slightly depressed.

B: Inspiration.

Lead I shows reduction in R and T.

Lead II shows increase in R and decrease in T.

Lead III shows increase in R and a practically flat T.

C: Expiration.

Lead I shows slight increase in R.

Lead II is unaltered.

Lead III shows increase in Q.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rS pattern. It faces the cavity of the right ventricle.

aVL has flat P and upright T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and shallow diphasic T waves and a qR pattern. It faces the epicardial surface of the left ventricle. The RT segment is slightly depressed.

The heart is vertical with forward rotation of the apex.

B: Inspiration.

aVR has a less inverted T.

aVL has an rS pattern with increase in S.

aVF shows increase in R.

The heart has become more vertical.

C: Expiration.

The patterns are very similar to the control series but aVL shows slight increase in R and T while aVF shows decrease in R and practically flat T.

The heart has become less vertical.

The Q wave in aVF is unaltered by respiration. The variation of the Q wave in lead III is due to the variation of the R wave in aVL.

The variation of the R wave in lead III is however due to the combined effect of the variation of the S wave in aVL and the R wave in aVF.

PRECORDIAL LEADS.

A: Control.

VI to V3 have rS patterns.

V4 and V5 have Rs patterns.

V6 has an R pattern.

P is diphasic in VI and notched in all other leads.

T is upright in all leads.

B: Inspiration.

VI to V3 have rS patterns with reduction in S.

V4 has an RS pattern with reduction in R.

V5 has an Rs pattern with reduction in R and increase in s.

V6 has an Rs pattern with reduction in R.

T is increased in V4 to V6.

There has been clockwise rotation of the heart.

C: Expiration.

The patterns are similar to the control series but S is reduced in VI to V3 and s is reduced in V4 and V5. R is increased in V6.

There has been counter-clockwise rotation of the heart.

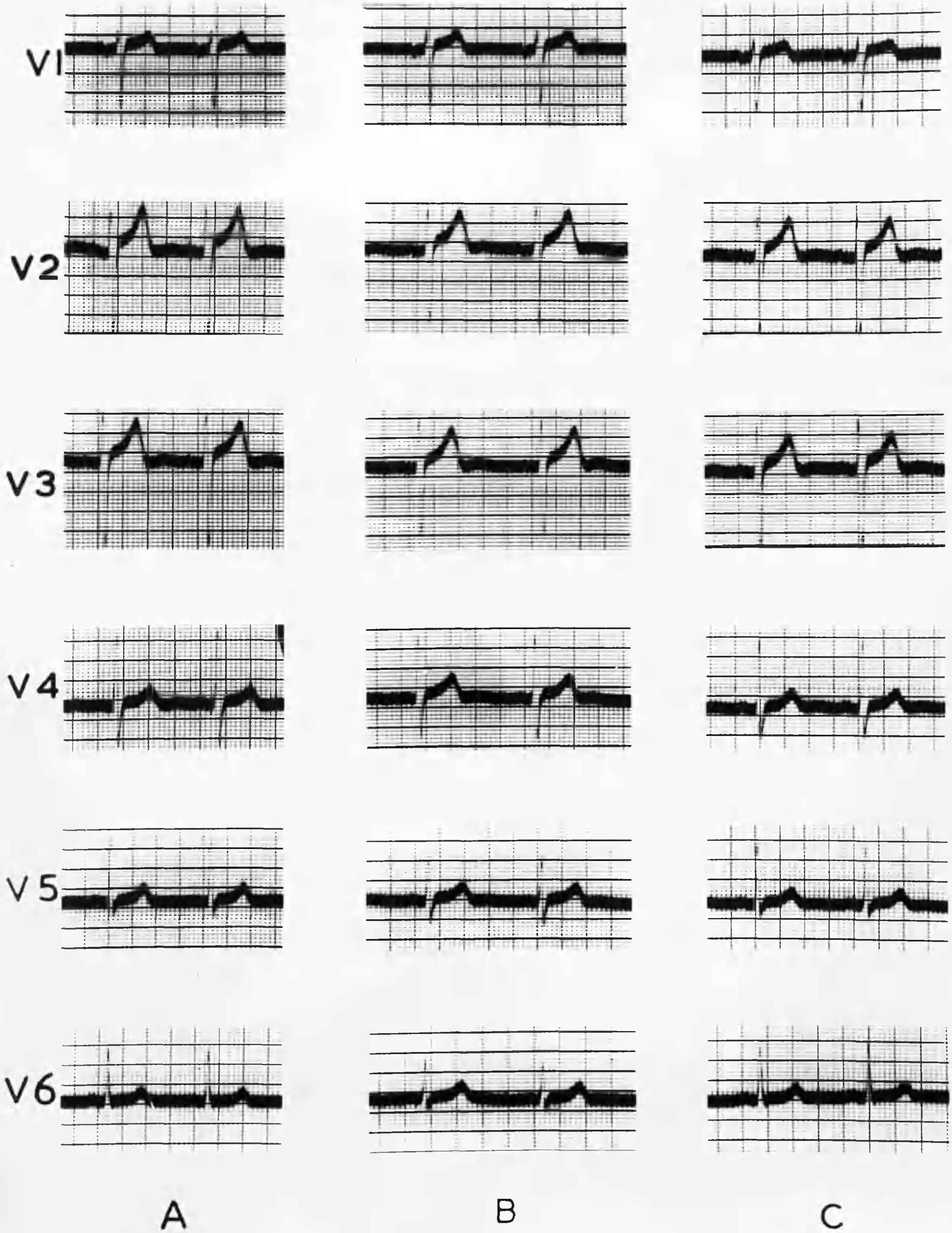
SUMMARY.

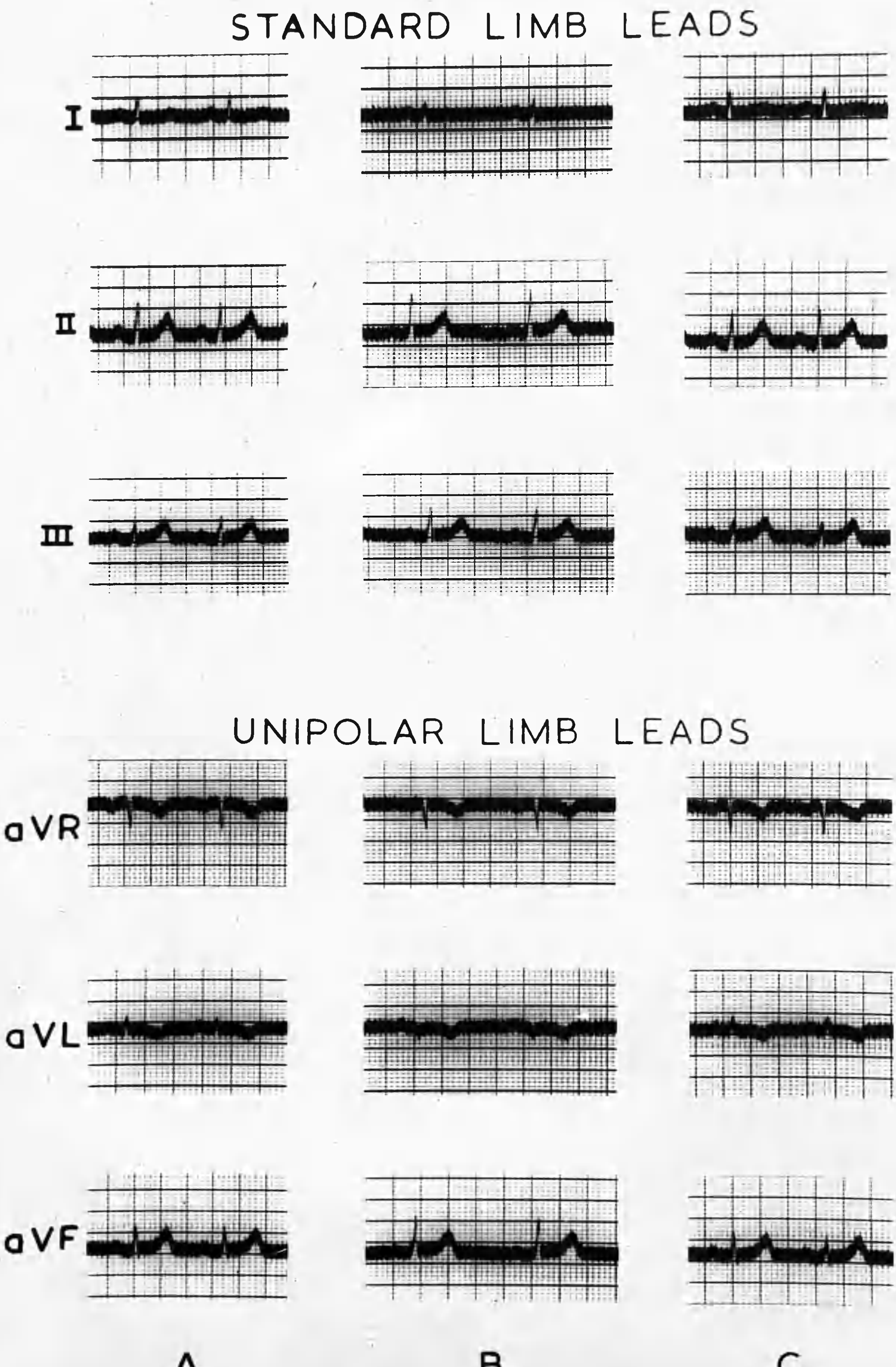
In this case the heart is vertical with marked clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation.

On expiration the heart becomes less vertical and undergoes counter-clockwise rotation.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.25

ABNORMAL.

H.W.

Diagnosis: Anterior Myocardial Infarction(healing).

Age 49 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and low upright T waves and an R pattern.

Leads II and III have upright P and tall upright T waves and Rs pattern.

B: Inspiration.

Lead I shows reduction in P wave; T is flat. There is an Rs pattern with reduction in R.

Lead II shows reduction in P and T and increase in R.

Lead III shows an R pattern with increased amplitude.

There has been a shift of the QRS axis to the right.

C: Expiration.

The patterns are similar to the control series but leads II and III show slight decrease in R.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has upright P and inverted T waves and an r pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and an Rs pattern. It probably faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR shows slightly less inverted P and T waves.

aVL shows increase in P and a more inverted T wave. There is a qs pattern.

aVF shows increase in R and decrease in s.

The heart has become more vertical and aVL is now more directly facing the infarcted surface.

C: Expiration.

aVR is unchanged.

aVL shows a slightly taller R while aVF shows a smaller R and deeper s.

PLATE II5b

PRECORDIAL LEADS.

A: Control.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has an R pattern.
P is upright in all leads.
ST segment is elevated in VI to V4.
T is diphasic in V2 to V4.

B: Inspiration.

VI to V3 have rS patterns with decrease in r.
V4 has an RS pattern with decrease in R and S.
V5 has an RS pattern with decrease in R.
V6 has an Rs pattern with decrease in R.
ST segment is elevated and T is diphasic in V2 to V4.
T is reduced in V5 and V6.
There has been clockwise rotation of the heart.

C: Expiration.

The patterns are similar to the control series.

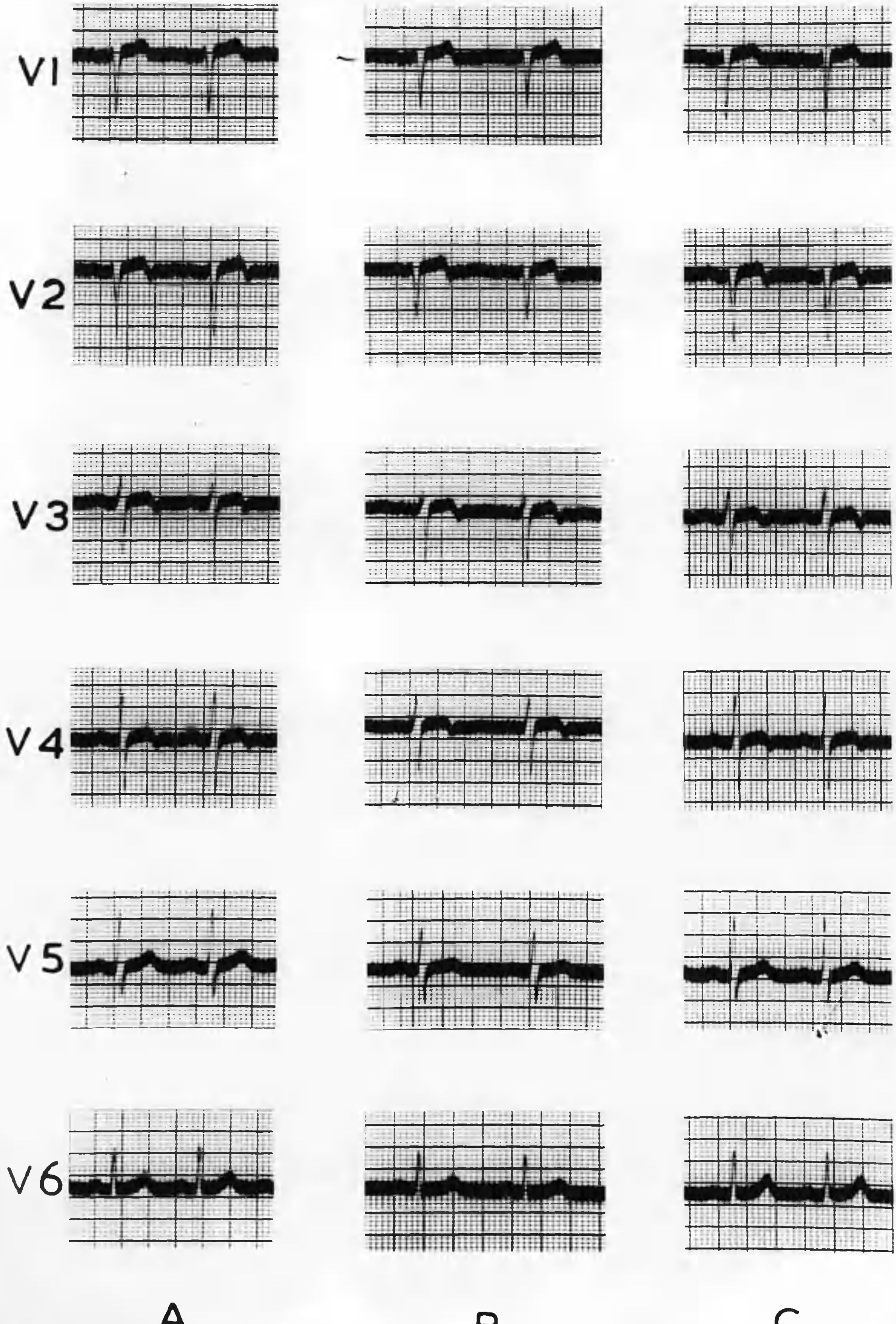
SUMMARY.

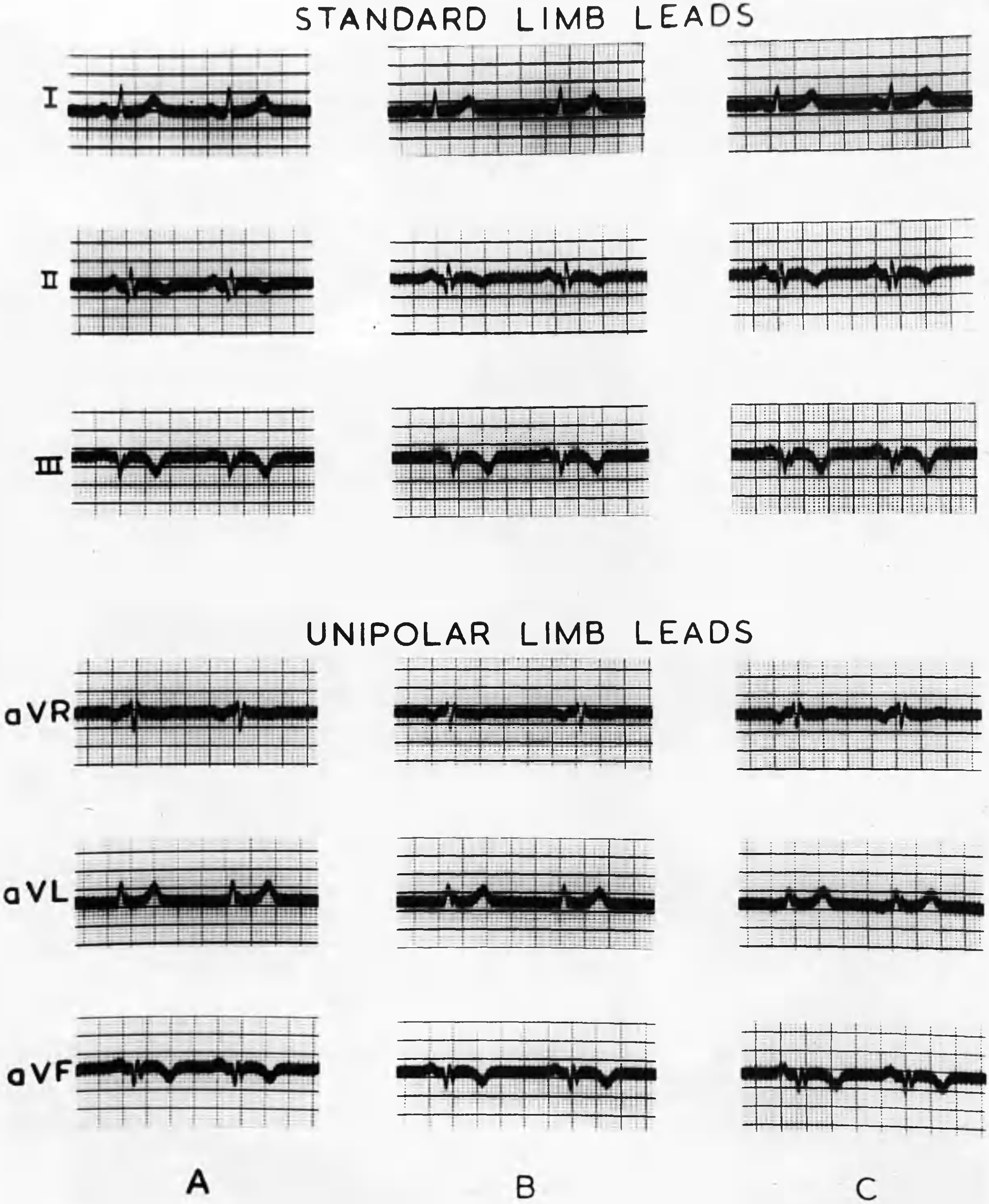
In this case the heart is vertical with marked clockwise rotation.

On inspiration the heart becomes more vertical and undergoes further clockwise rotation with backward rotation of the apex.

On expiration no significant changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 26

ABNORMAL. E.McK.

Diagnosis: Posterior Myocardial Infarction (healed). Age 42 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an Rs pattern.

Lead II has upright P and inverted T waves and a QRs pattern.

Lead III has upright P and deeply inverted T waves and a splintered QS pattern.

B: Inspiration.

Lead I shows decrease in R and T.

Lead II shows decrease in R and slightly less inverted T.

Lead III shows a Qrs pattern and less inverted T.

C: Expiration.

Lead I shows slight reduction of R and T.

Lead II shows reduction of R and increase of s and a more deeply inverted T.

Lead III is unaltered.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and shallow inverted T waves and an rSr' pattern. It probably faces the epicardial surface of the right ventricle.

aVL has flat P and tall upright T waves and a splintered R pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and deeply inverted T waves and a Qrs pattern. It faces the infarcted surface of the left ventricle.

The heart is vertical with forward rotation of the apex.

B: Inspiration.

The patterns are similar to the control series but aVL shows reduction in R and T, and aVF shows increase in r.

The heart has become slightly more vertical.

C: Expiration.

aVR shows decrease in S and increase in r';

T is low upright.

aVL shows decrease in R and a deeper notch. T is slightly decreased.

aVF shows smaller r and deeper s.

The heart has become slightly less vertical and there has been forward rotation of the apex.

PRECORDIAL LEADS.

A: Control.

VI has an rS pattern.

V2 and V3 have RS patterns.

V4 to V6 have Rs patterns.

P is diphasic in VI and upright in all other leads.

T is upright and tall in all leads.

B: Inspiration.

The patterns are very similar to the control series but there is slight increase of S in V3 and of s in V4 to V6, while R is decreased in V5 and V6.

There has been slight clockwise rotation of the heart.

C: Expiration.

The patterns are similar to the control series, but R is slightly reduced in V3 to V6 and s is increased in V5 and V6.

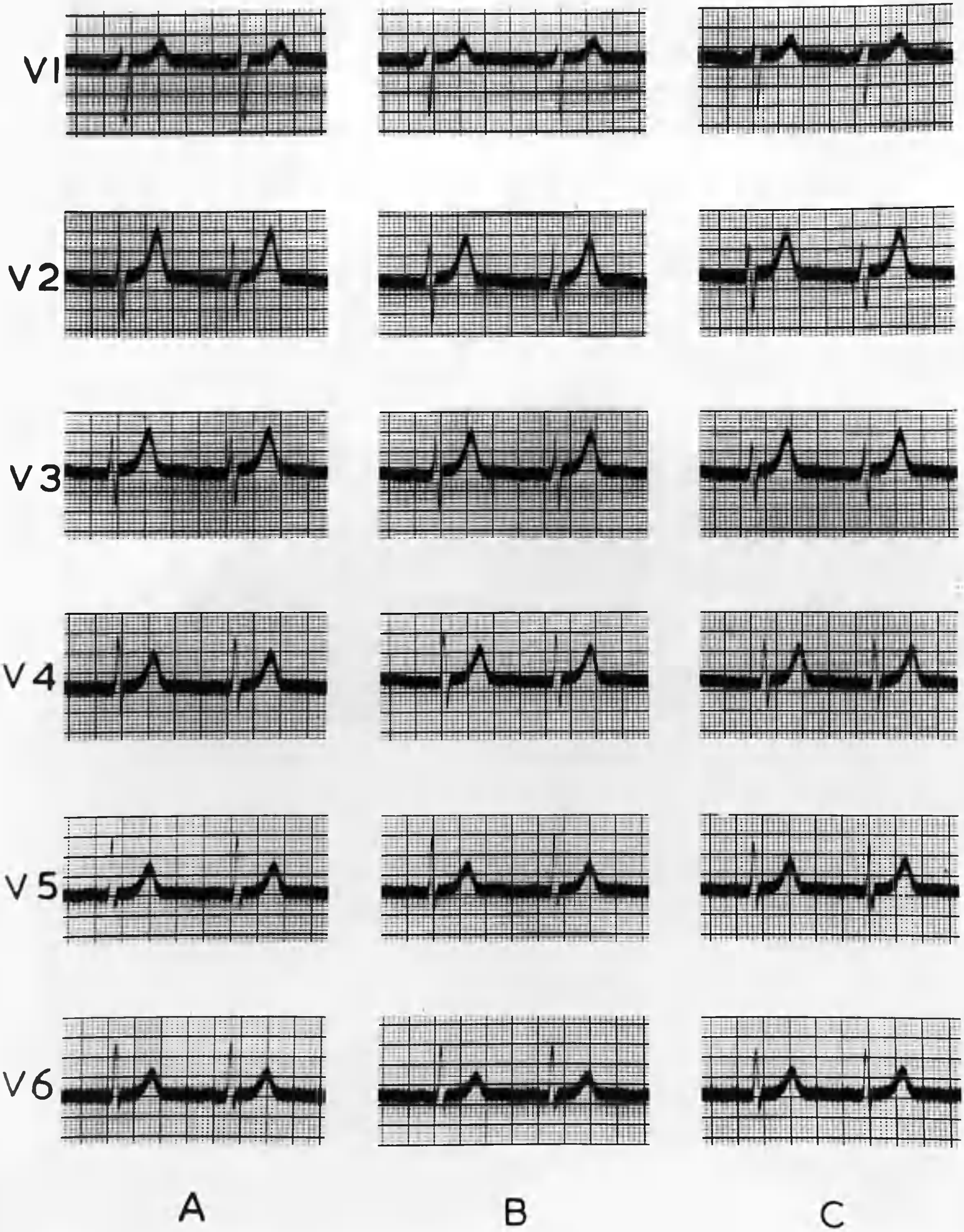
This may be due to the heart becoming more horizontal.

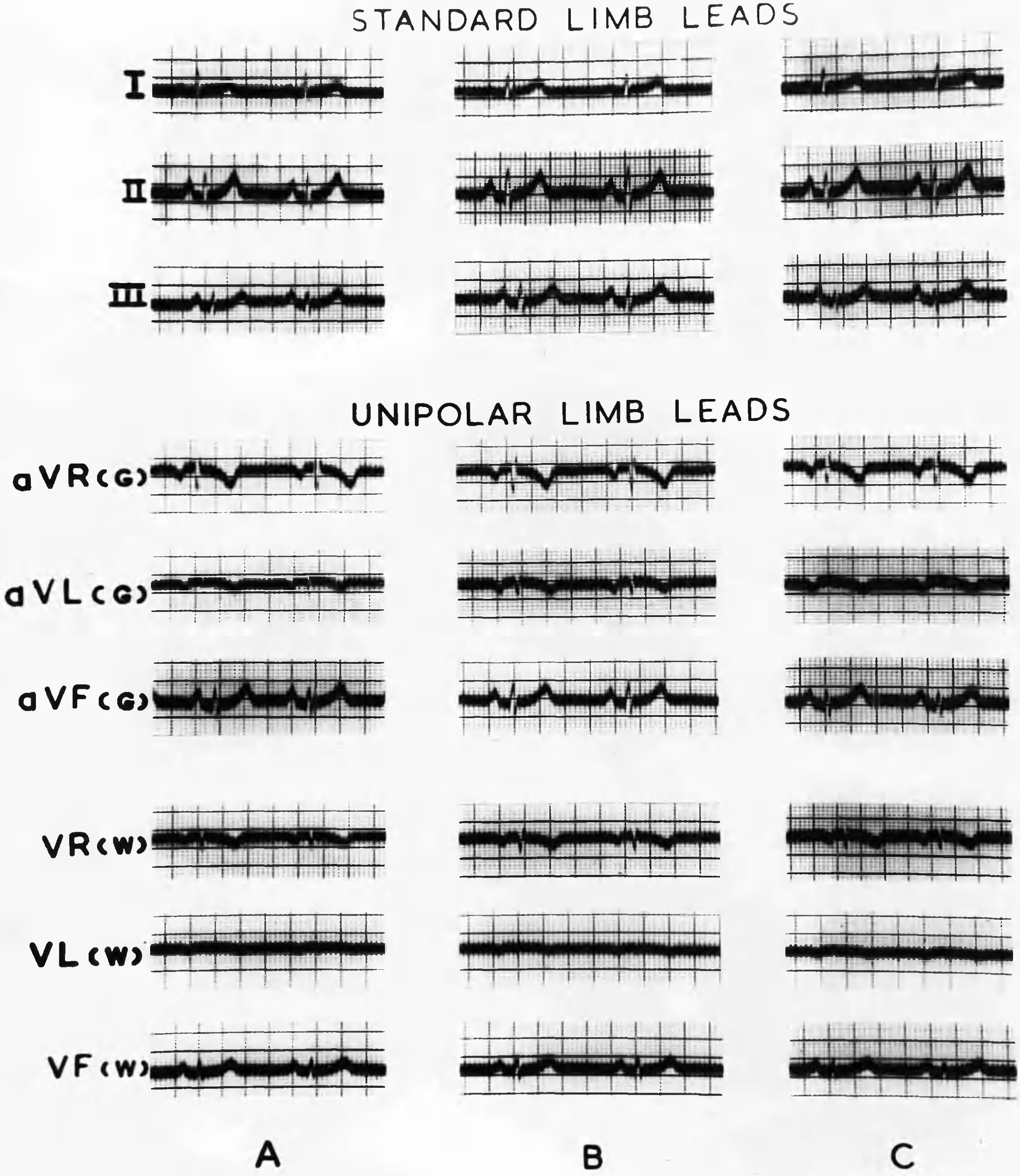
SUMMARY.

In this case the heart is vertical with ~~marked~~ clockwise rotation and forward rotation of the apex.

Respiration causes relatively little change. On inspiration the heart becomes slightly more vertical and undergoes slight clockwise rotation. On expiration the heart becomes slightly more horizontal.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
A
B
C

CASE NO. 27

ABNORMAL. J.B.

Diagnosis: Chronic Bronchitis and Emphysema. Age 50 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an Rs pattern.

Lead II and lead III have abnormally tall upright P waves, upright T waves and qRs patterns.

B: Inspiration.

The basic patterns are unchanged but lead I shows reduction in P and R; lead II shows increase in P and R and deeper s; lead III shows increase in P,R and T.

There has been a shift of the QRS axis to the right.

C: Expiration.

Lead I is similar to the control.

Lead II shows decrease in R and increase in s.

Lead III has a qRS pattern with reduction in R.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

aVL has less deeply inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRS pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical with forward rotation of the apex.

B: Inspiration.

The basic patterns are unchanged but aVR shows slightly deeper S; aVL shows deeper P,S and T; aVF shows taller R.

The heart has become more vertical.

C: Expiration.

aVR still shows an rSr' pattern with reduction in S.

aVL shows an rsr' pattern.

aVF still has a qRS pattern with reduction in R.

The heart has become less vertical.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PRECORDIAL LEADS.

A: Control.

V1 to V4 have rS patterns.

V5 and V6 have RS patterns.

P is diphasic in V1 and V2 and upright in all other leads.

T is upright and tall in all leads.

B: Inspiration.

The patterns are identical with the control series.

There has been no significant rotation of the heart .

C: Expiration.

The patterns are identical with the control series.

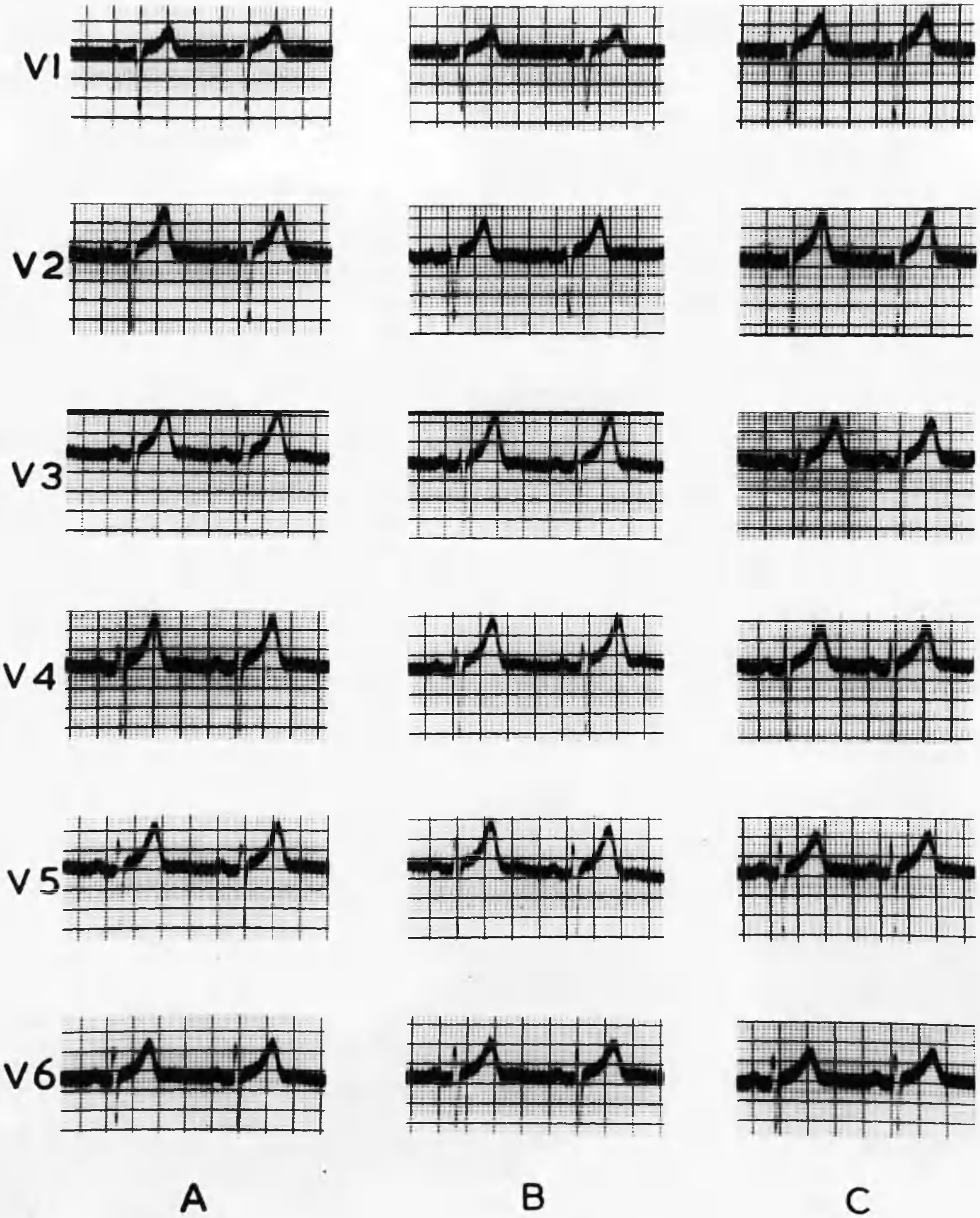
There has been no significant rotation of the heart.

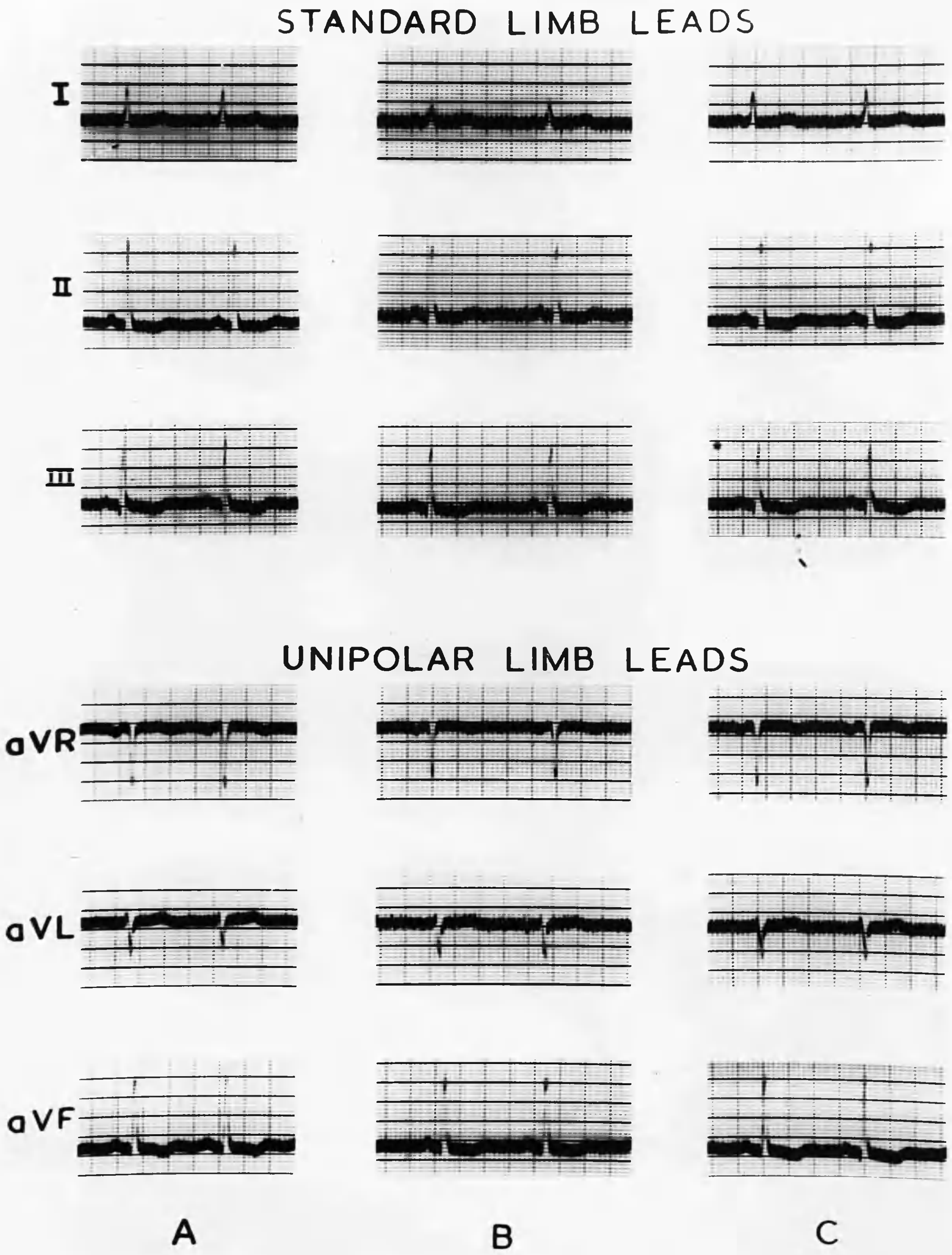
SUMMARY.

This is a vertical heart with marked clockwise rotation and forward rotation of the apex.

Respiration produces relatively little change though on inspiration the heart becomes slightly more vertical, and on expiration slightly less vertical.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

ABNORMAL. Mrs.E.McC.

Diagnosis: Essential Hypertension. Age 45 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an R pattern.

Lead II has upright P and shallow diphasic T waves and a qR pattern. The RT segment is depressed.

Lead III has upright P and inverted T waves and a qR pattern. The RT segment is depressed.

B: Inspiration.

Lead I shows reduction in P, R and T.

Lead II shows reduction in R; T is low upright and the RT segment is almost iso-electric.

Lead III shows increase in P and slight increase in R; T is less inverted.

C: Expiration.

Lead I is unchanged.

Lead II shows decrease in R; T is slightly more inverted.

Lead III shows slight decrease in R; T is unaltered.

UNIPOLAR LIMB LEADS.

A: Control

aVR has inverted P and shallow inverted T waves and a QS pattern. It faces the cavity of the left ventricle. The ST segment is slightly elevated.

aVL has flat P and low upright T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and inverted T waves and a qR pattern. The RT segment is slightly depressed. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

The basic patterns are unaltered but aVR shows a smaller QS and less inverted T; aVL shows a deeper S and smaller T; aVF shows less inverted T.

The heart has become more vertical.

C: Expiration.

The patterns are identical with the control series.

PRECORDIAL LEADS.

A: Control.

VI to V3 have rS patterns.
V4 has an Rs pattern.
V5 and V6 have R patterns.
P and T are upright in all leads.
The ST segment is elevated in VI to V4 and depressed in V6.

B: Inspiration

VI to V3 have rS patterns with increase in S in V3.
V4 has an RS pattern with decrease in R.
V5 and V6 have Rs patterns with decrease in R.
P is diphasic in VI and upright in all other leads.
T is decreased in V2 and increased in V3 to V5.
There has been clockwise rotation of the heart.

C: Expiration.

The patterns are similar to the control series.

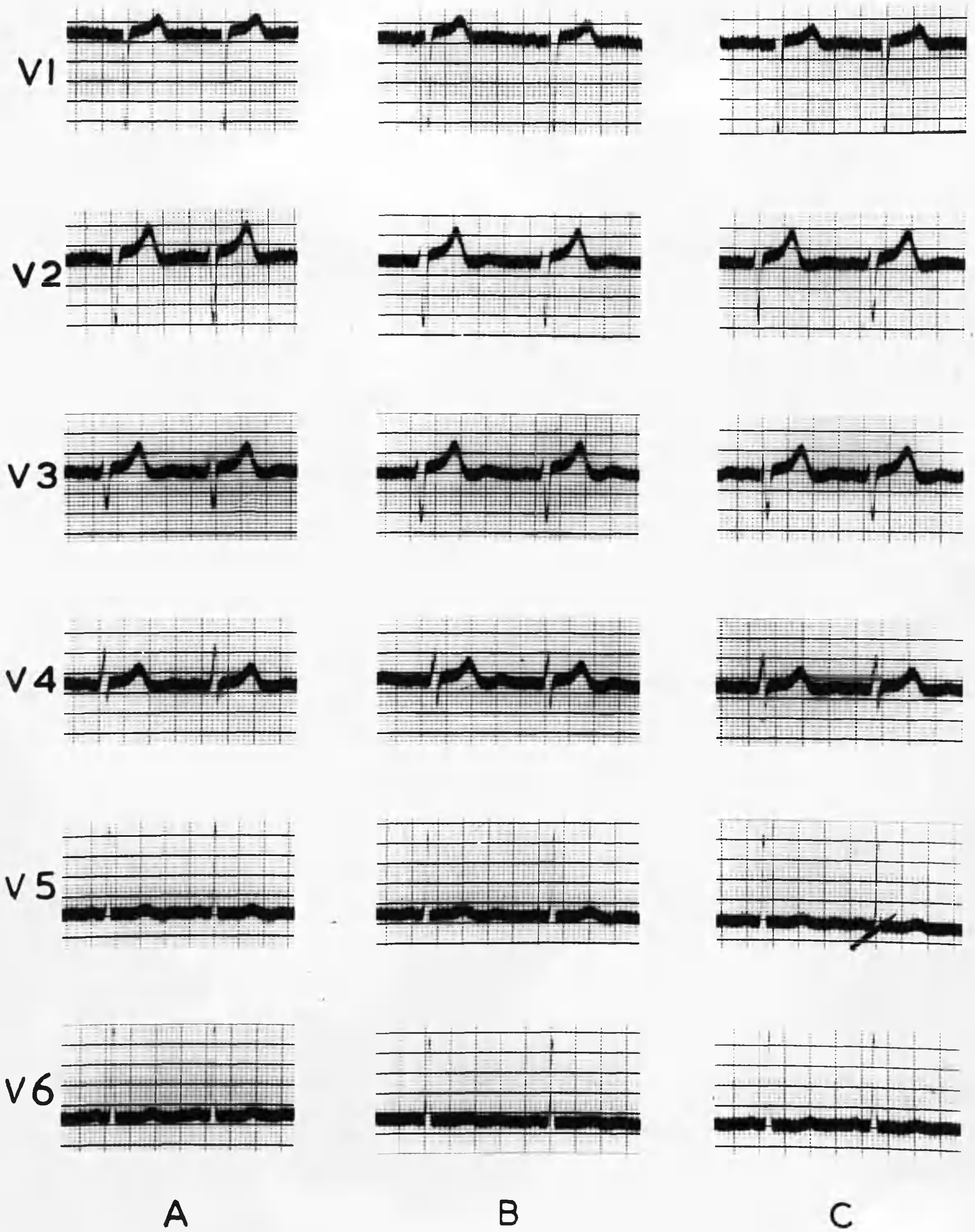
SUMMARY.

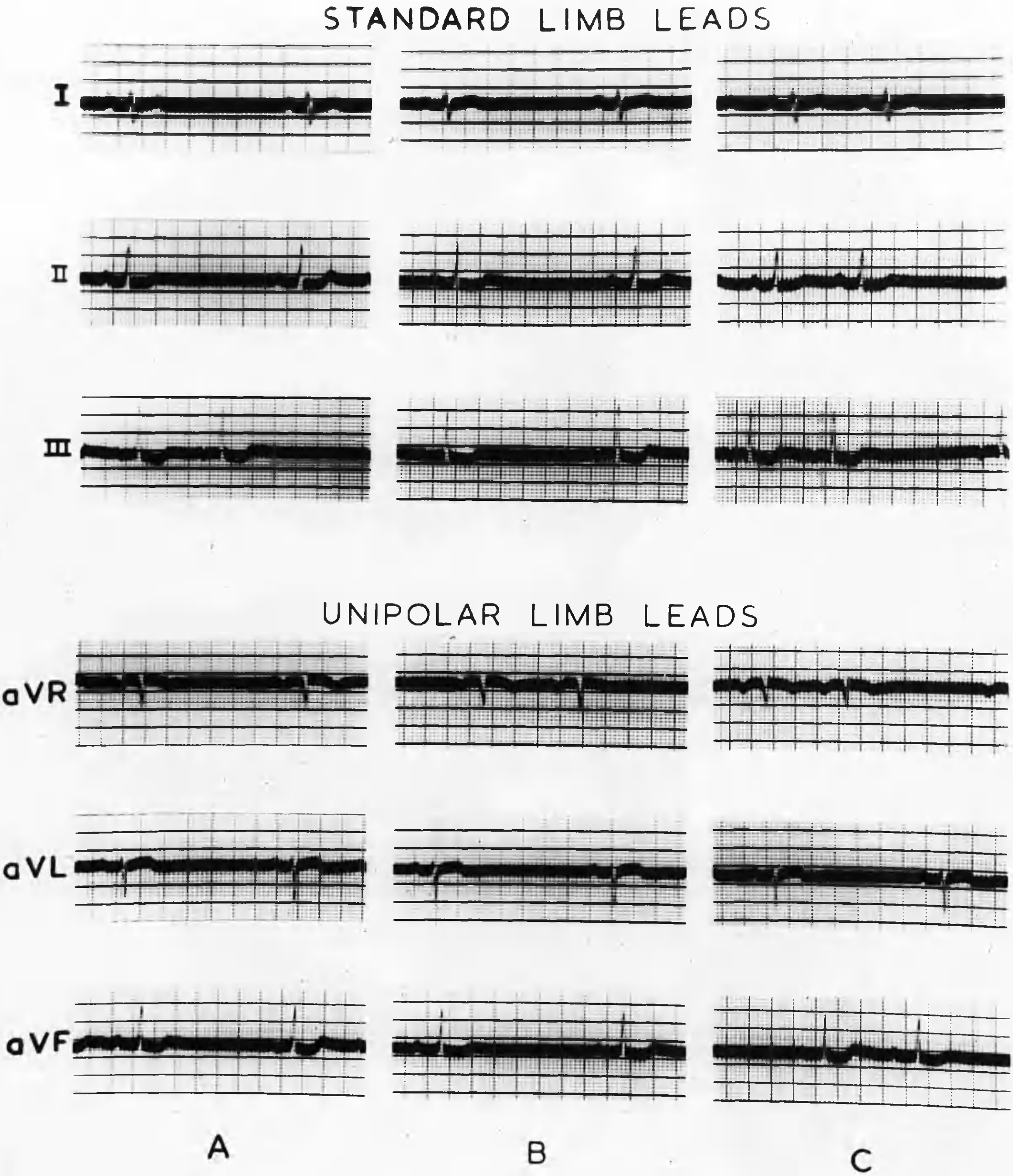
In this case the heart is vertical with marked clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes slightly more vertical and undergoes clockwise rotation.

On expiration no significant changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

ABNORMAL. A.B.

Diagnosis: Mitral Stenosis, Chronic Adhesive Pericarditis. Age I9 years.

STANDARD LIMB LEADS.

A: Control

Lead I has upright P and T waves and an RS pattern.

Lead II has upright P waves and a qRs pattern; T is diphasic and the ST segment is depressed.

Lead III has diphasic P waves and a qR pattern; T is inverted and the RT segment is depressed.

There is right axis deviation and digitalis effect including sinus block.

B: Inspiration.

Lead I shows decrease in P,R and T and slight increase in S.

Lead II shows an Rs pattern.

Lead III shows a qR pattern with slight increase in R.

There has been a shift of the QRS axis to the right.

C: Expiration.

The tracings are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a Qr pattern; the RT segment is elevated. It tends to face the back of the heart.

aVL has upright P and T waves and an rS pattern; the ST segment is elevated. It probably faces the epicardial surface of the right ventricle.

aVF has diphasic P waves and a slurred qR pattern; T is diphasic and the RT segment is depressed. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

The patterns are similar to the control series.

There has been no significant change in the position of the heart.

C: Expiration.

The patterns are similar to the control series.

There has been no significant change in the position of the heart.

PLATE II9b

PRECORDIAL LEADS.

A: Control.

VI to V4 have RS patterns.

V5 and V6 have Rs patterns.

P is diphasic in VI and upright in all other leads.

T is inverted in VI and diphasic but mainly negative in all other leads.

The ST segment is depressed in all leads.

B: Inspiration.

The patterns are similar to the control series but in VI there is reduction of R and S and T is less inverted; in V2 to V4 S is increased;in V5 and V6 s is increased.

There has been slight clockwise rotation of the heart.

C: Expiration.

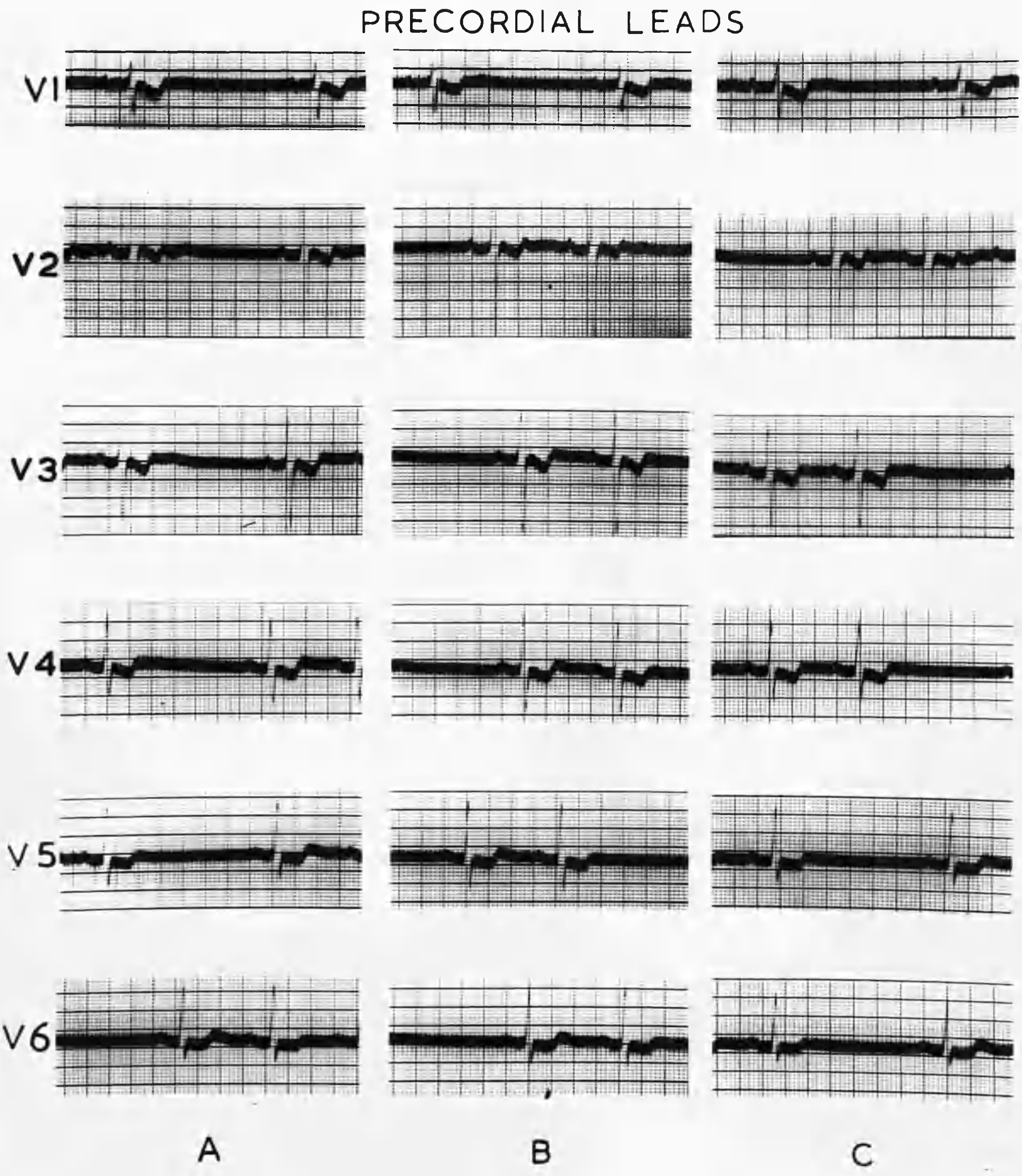
The patterns are similar to the control series but in V3 and V4 there is decrease in S and in V5 and V6 there is decrease in s.

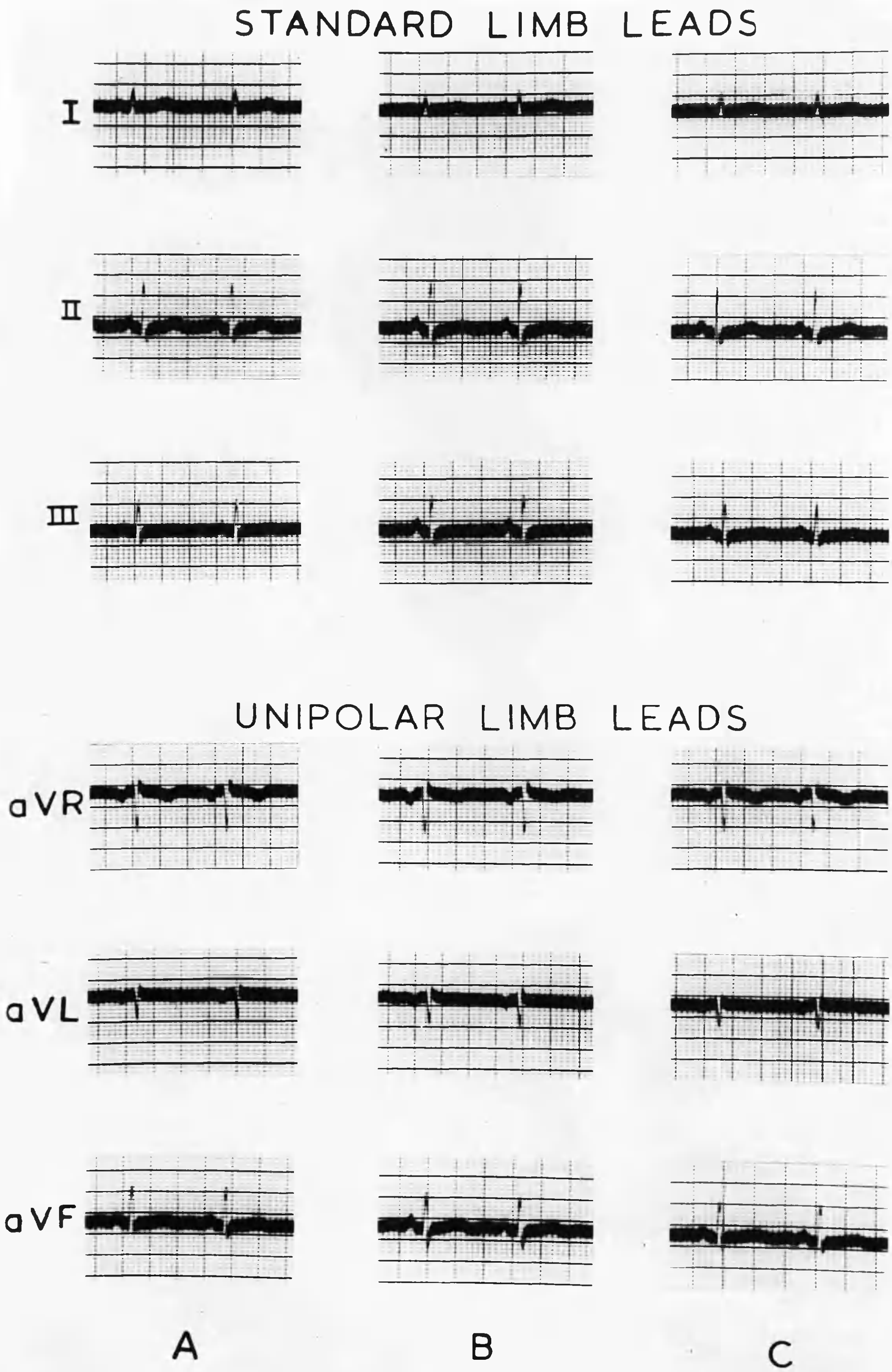
There has been counter-clockwise rotation of the heart of slight degree.

SUMMARY.

In this case the heart is vertical with marked clockwise rotation and forward rotation of the apex.

Respiration causes relatively little change in the position of the heart; on inspiration there is slight clockwise rotation and on expiration slight counter-clockwise rotation.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO.30 PLATE 120a

ABNORMAL. Mrs. H.M.

Diagnosis: Thyrotoxicosis. Age 40 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an Rs pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has upright P and low upright T waves and a qRs pattern.
There is a tendency to right axis deviation.

B: Inspiration.

Lead I shows a slight decrease in all waves.
Lead II shows increase in P and R and flattening of T.
Lead III shows increase in P and R and flattening of T.
There has been a slight shift of the QRS axis to the right.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.
aVL has inverted P and flat T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.
aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.
The heart is vertical.

B: Inspiration.

aVR shows flattening of T.
aVL shows slight increase in S.
aVF shows an Rs pattern with increase in s.
The heart has become slightly more vertical and there has been backward rotation of the apex so that aVL tends to face the epicardial surface of the right ventricle.

C: Expiration.

The patterns are identical with the control series.

PRECORDIAL LEADS.

A: Control.

V1 has an rSr' pattern.
V2,V3 and V4 have rS patterns.
V5 has an RS pattern.
V6 has an Rs pattern.
V1 has inverted P and flat T waves; all other leads have flat P and upright T waves.

B: Inspiration.

V1 has deeper S and low upright T waves.
V2 has deeper S waves.
V3 and V4 have small S waves.
Both V5 and V6 have RS patterns.
There has been some clockwise rotation.

C: Expiration.

The patterns are identical with the control series.

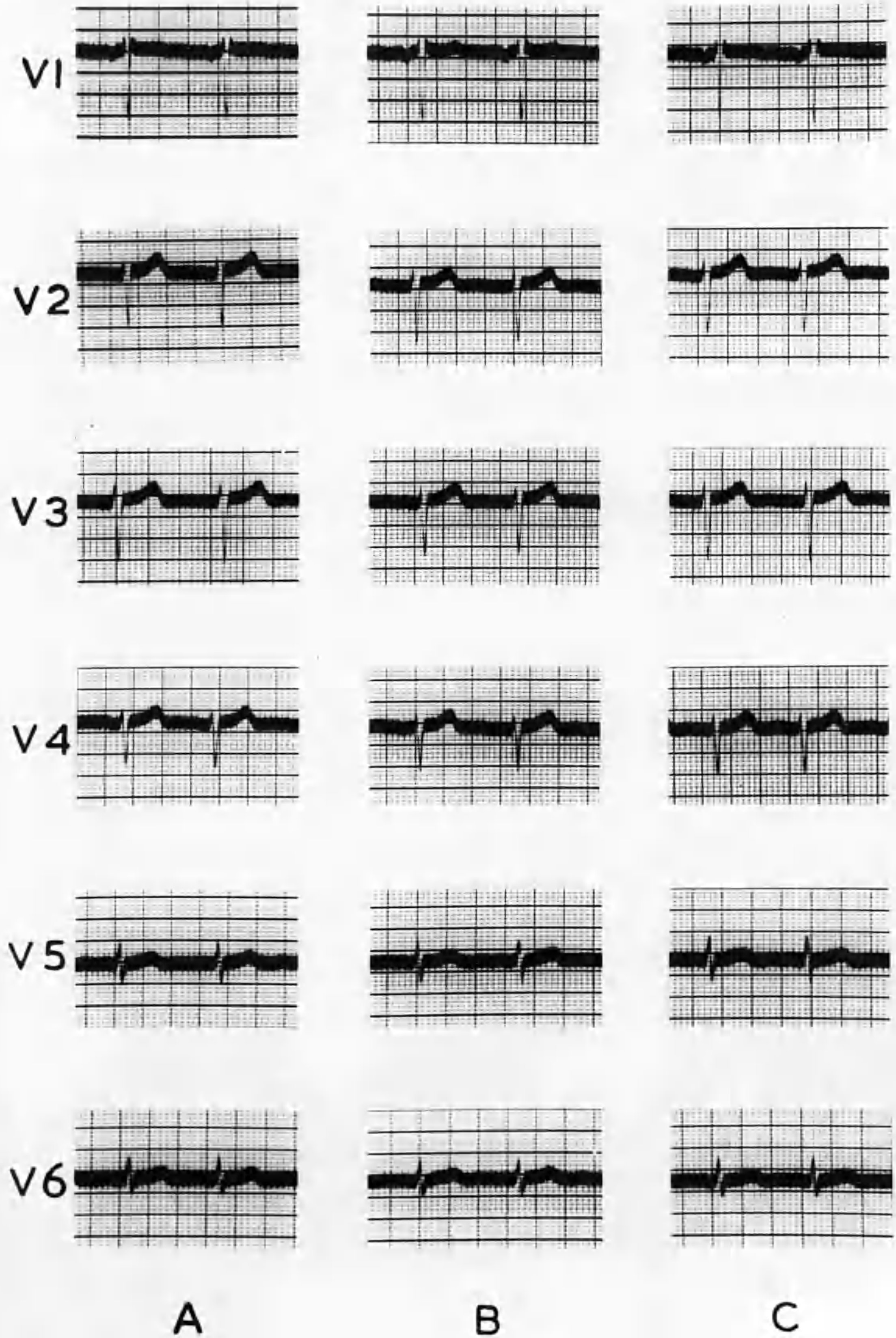
SUMMARY.

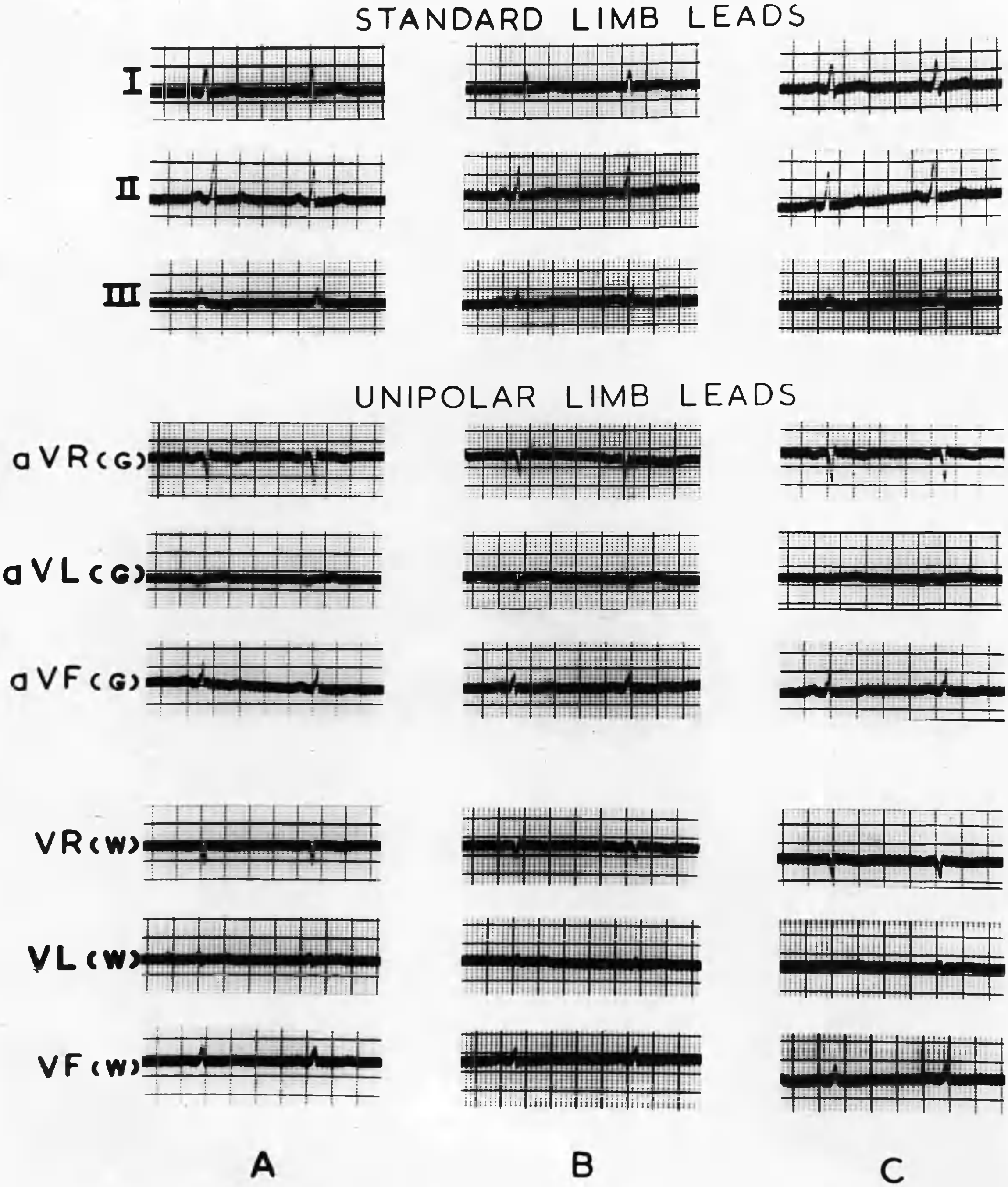
This is a normal vertical heart with marked clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes still more vertical and undergoes some clockwise rotation round its long axis with concomitant backward rotation of the apex.

On expiration no obvious changes occur.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR (G)
aVL (G)
aVF (G)
VR (W)
VL (W)
VF (W)
A
B
C

CASE NO. 31 PLATE 121a

ABNORMAL. H. McC.

Diagnosis: Chronic Cholecystitis. age 27 years.

STANDARD LIMB LEADS.

A: Control.

Leads I and II have upright P and T waves and Rs patterns.

Lead III has low upright P and shallow diphasic T waves and a splintered R pattern.

B: Inspiration.

Lead I shows reduction in P,R,s and T.

Lead II shows reduction in R and T.

Lead III shows increase in P; T is still diphasic but more upright. There is a splintered Rsr' pattern with increase in R.

C: Expiration.

The patterns are similar to the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a Qr pattern. It tends to face the back of the heart.

aVL has flat P and upright T waves and a small vibratory qrsr's' pattern. It probably faces the interventricular epicardial region.

aVF has upright P and low upright T waves and a slurred Rs pattern. It probably faces the epicardial surface of the right ventricle.

The heart is semi-vertical with backward rotation of the apex.

B: Inspiration.

aVR shows less inverted P and T waves; Q is reduced.

aVL shows slight inversion of P and an rSr's' pattern.

aVF still has a slurred Rs pattern with reduction in R and increase in s. T is practically flat.

The heart has become more vertical and there has been backward rotation of the apex.

C: Expiration.

The patterns are similar to the control series.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PRECORDIAL LEADS.

A: Control.

VI has a QS pattern.
V2 to V6 have Rs patterns.
P and T are upright in all leads.

B: Inspiration.

VI has a qrS pattern, with a decrease in S.
V2 has an RS pattern with reduction in R.
V3 to V6 have Rs patterns with reduction in R.
There has been slight clockwise rotation of the heart.

C: Expiration.

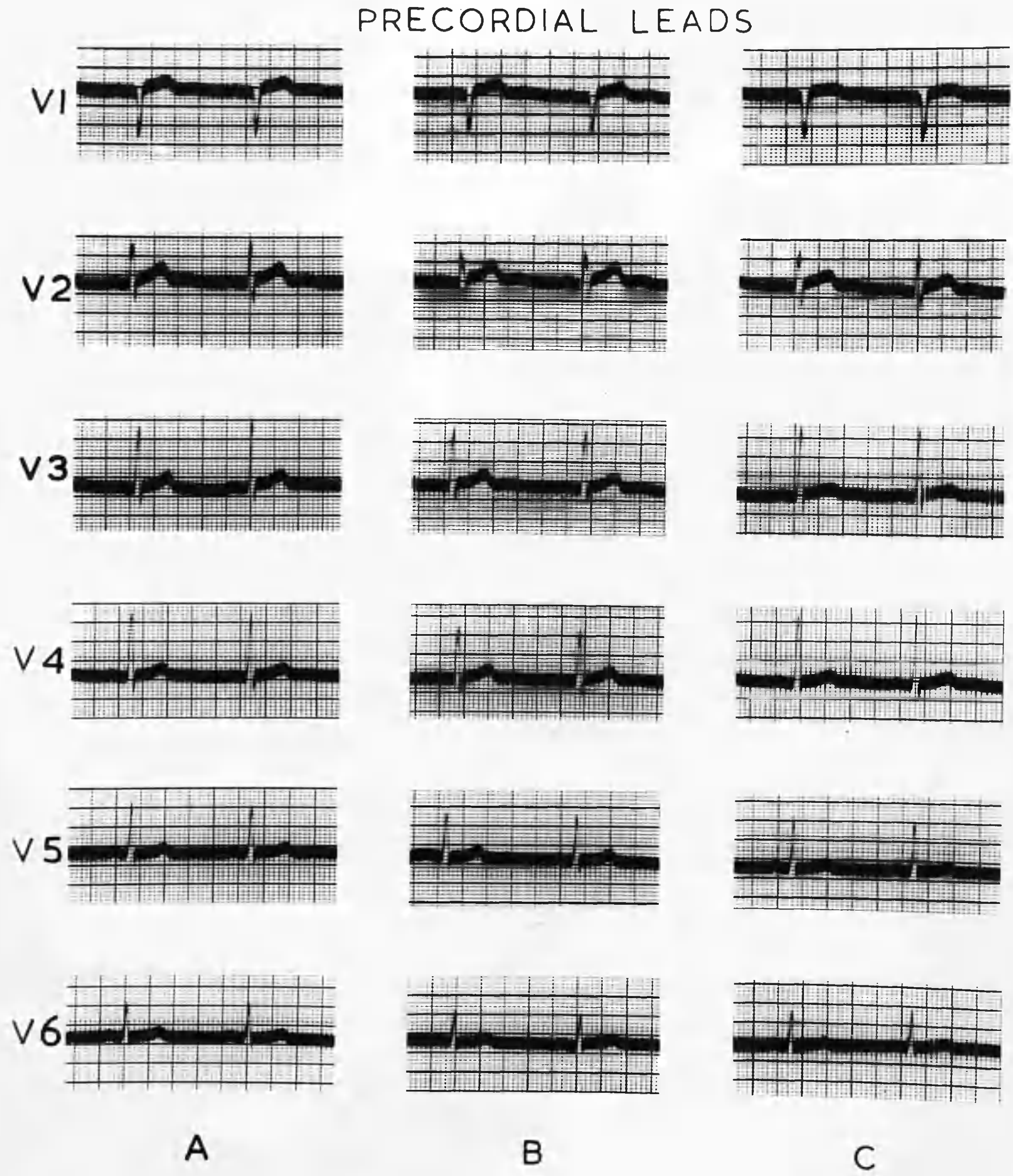
The patterns are similar to the control series but there is slight increase in R in V3 to V6.

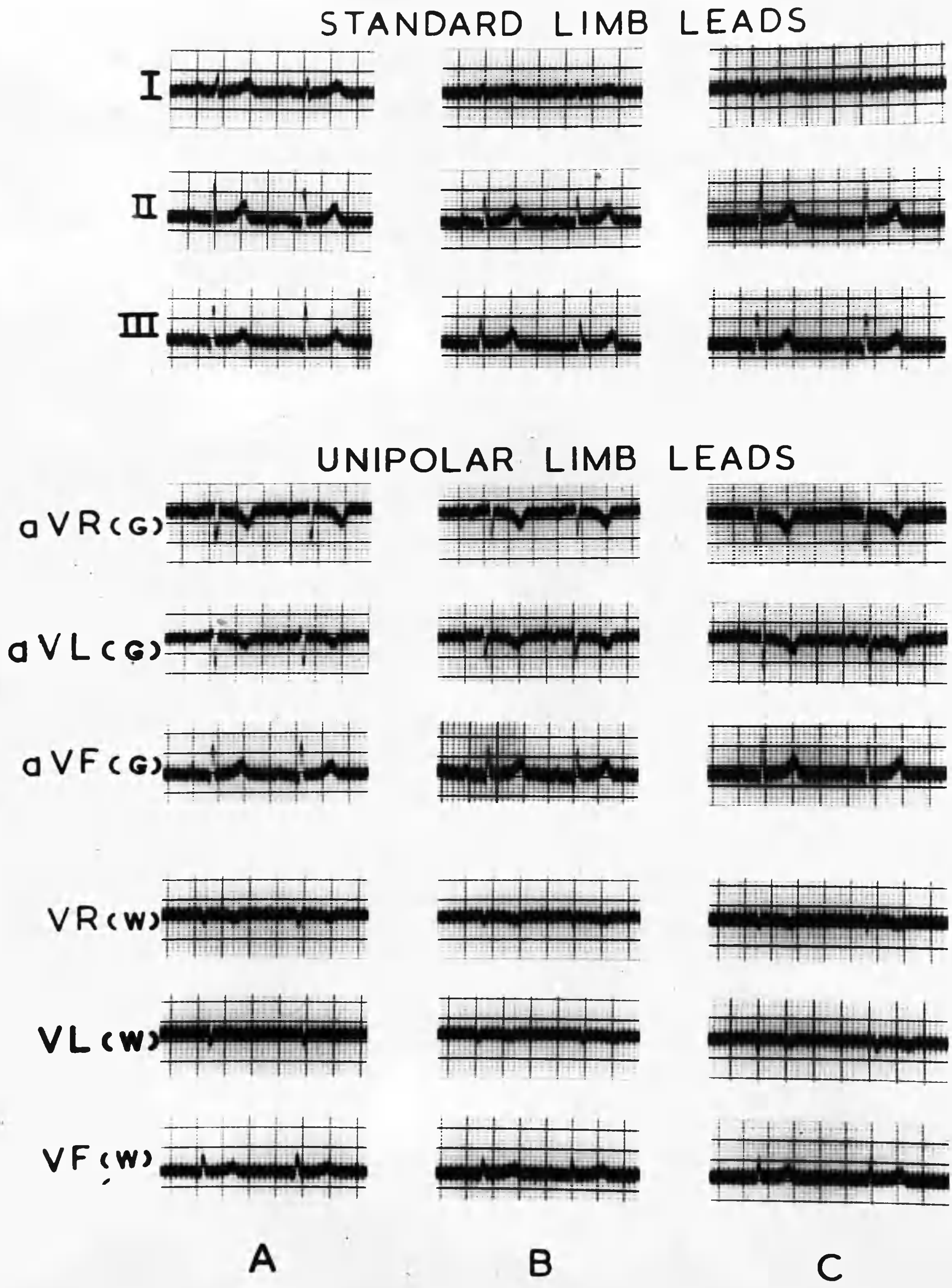
SUMMARY.

This is a semi-vertical heart with marked clockwise rotation and backward rotation of the apex.

On inspiration the heart becomes slightly more vertical and undergoes further clockwise rotation, with backward rotation of the apex.

On expiration no significant changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR (G)
aVL (G)
aVF (G)
VR (W)
VL (W)
VF (W)
A
B
C

CASE NO. 32 PLATE I22a

ABNORMAL. D.W.

Diagnosis: Idiopathic Steatorrhoea. Age I8 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and an Rs pattern.

Lead II has upright P and T waves and a qRs pattern.

Lead III has diphasic P and upright T waves and a qR pattern.

There is a tendency to right axis deviation.

B: Inspiration.

Lead I shows reduction of P and T and an rs pattern.

Lead II shows reduction in T and a qR pattern with reduction in R.

Lead III has inverted P and increased T waves and reduction in R.

C: Expiration.

Lead I shows reduction in T and an Rs pattern with reduction in R.

Lead II is unchanged.

Lead III shows slight reduction in R and increase in T.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has inverted P and T waves and an rS pattern. It faces the cavity of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

B: Inspiration.

aVR shows reduction in QS.

aVL shows reduction in r and S and more deeply inverted T.

aVF shows a qR pattern with reduction in R; T is increased.

C: Expiration.

aVR shows deeper QS and T.

aVL shows deeper S and T; P is diphasic.

aVF shows reduction in q and increase in R; T is increased.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PRECORDIAL LEADS.

A: Control.

VI to V3 have rS patterns.
V4 and V5 have RS patterns.
V6 has an Rs pattern.
P and T are upright in all leads.

B: Inspiration.

VI to V4 have rS patterns with decrease in r in all and of S in VI and V2.
V5 has an RS pattern with decrease in R and S.
V6 has an RS pattern with decrease in R.
T is reduced in all.
There has been clockwise rotation of the heart.

C: Expiration.

VI to V3 have appearances intermediate between the control series and inspiration.
V4 is identical with the control.
V5 and V6 resemble the tracings of inspiration.
These appearances are difficult to interpret.

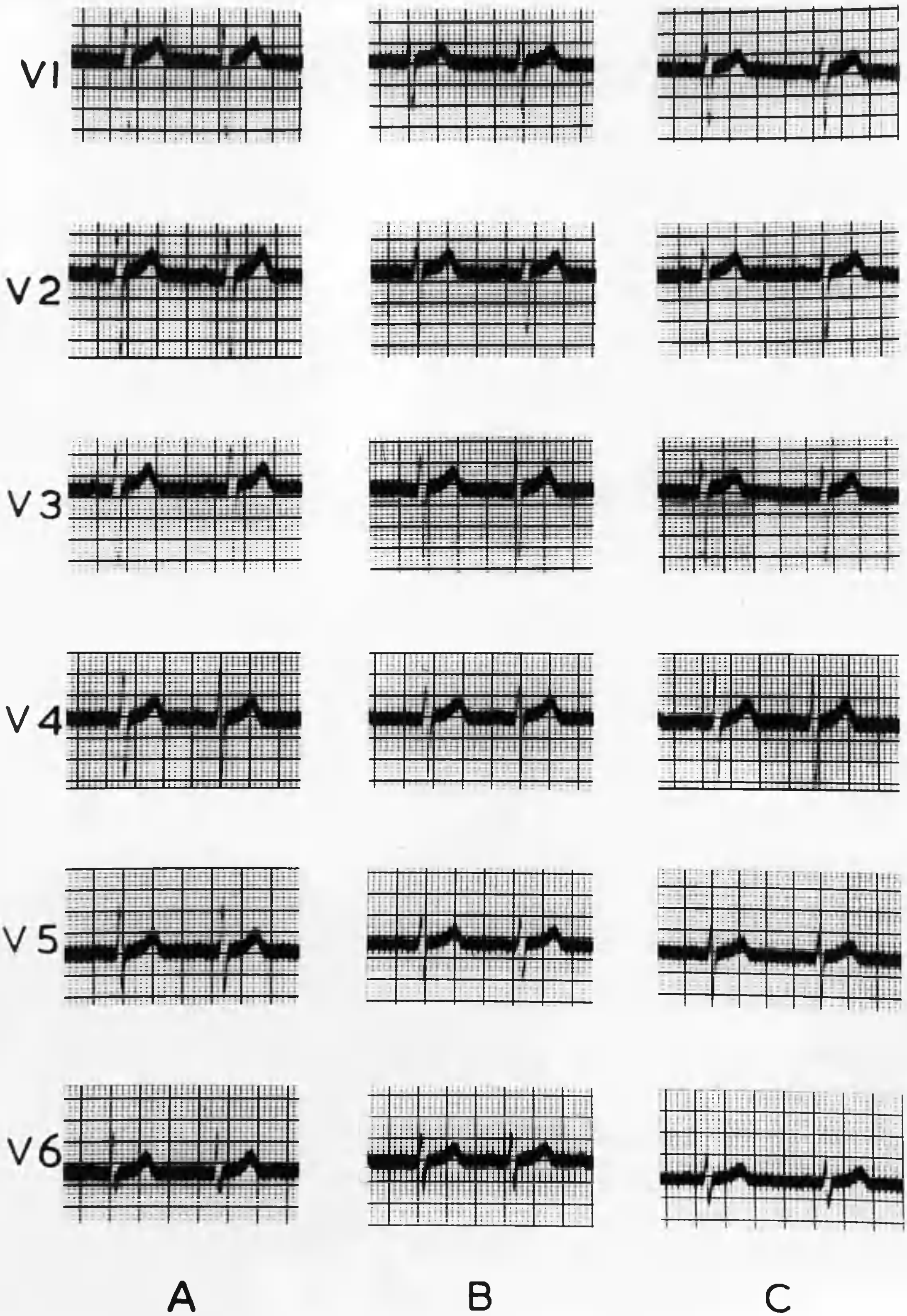
SUMMARY.

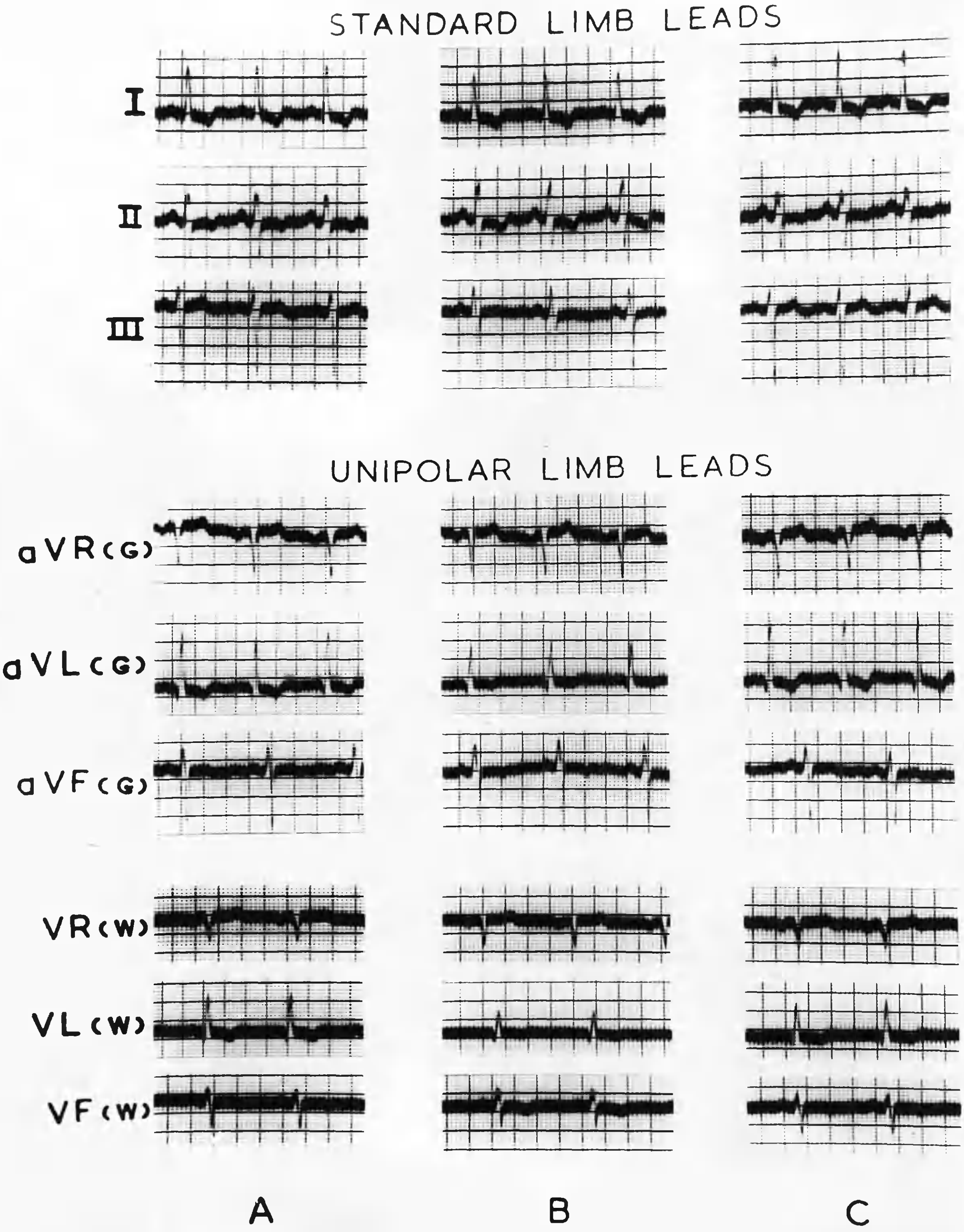
In this case the heart is vertical with marked clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation.

On expiration the heart probably becomes more horizontal.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
A
B
C

CASE NO. 33 PLATE I23a

ABNORMAL. R.R.

Diagnosis: Malignant Hypertension. Age 34 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has a qR pattern ; P is upright, T is inverted and there is depression of the RT segment.

Lead II has an RS pattern; P is upright , T is diphasic but mainly negative and there is depression of the ST segment.

Lead III has an rS pattern; P is upright, T is upright and there is elevation of the ST segment.

The pattern is that of left ventricular hypertrophy and strain.

B: Inspiration.

Lead I shows reduction in P and R.

Lead II shows increase in R and decrease in S; T is more inverted and the ST segment is more depressed.

Lead III shows increase in P and r and decrease in S; T is flat and the ST segment is isoelectric.

C: Expiration.

Lead I shows increase in R.

Lead II shows decrease in R; T is diphasic but less negative, and the ST segment is less depressed.

Lead III shows increase in S; T is increased and the ST segment is slightly more elevated.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has a QS pattern; P is inverted, T is upright and the ST segment is elevated. It probably faces the cavity of the left ventricle.

aVL has a qR pattern; P is flat, T is inverted and there is depression of the RT segment. It faces the epicardial surface of the left ventricle.

aVF has an rS pattern; P is upright, T is shallow and diphasic. The ST segment is isoelectric.

The heart is horizontal.

B: Inspiration.

aVR shows a deeper QS; P is more inverted and T is taller.

aVL shows decrease in R; T is less inverted and the RT segment is less depressed.

aVF shows increase in r and decrease in S; P is increased, T is inverted and the ST segment is isoelectric.

The heart has become less horizontal.

C: Expiration.

aVR is unaltered.

aVL shows increase in R; T is more deeply inverted and the RT segment is more depressed.

aVF shows decrease in r; T is low upright and the ST segment is slightly elevated.

The heart has become more horizontal.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PRECORDIAL LEADS.

A: Control.

V1 and V2 have rS patterns. P and T are upright, and the ST segment is elevated.

V3 has an rsR'S' pattern; P and T are upright and the ST segment is slightly elevated.

V4 has a qRs pattern; P is upright, T is diphasic and the ST segment is depressed.

V5 and V6 have qR patterns; P is upright, T is inverted and the RT segment is depressed.

B: Inspiration.

V1 and V2 show reduction in S.

V3 shows reduction in R' and S'; ST is more elevated.

V4 has an Rs pattern with reduction in R and s; ST is isoelectric and T upright.

V5 and V6 show reduction in q and R; T is less inverted.

There has been clockwise rotation of the heart.

C: Expiration.

The patterns are very similar to the control series.

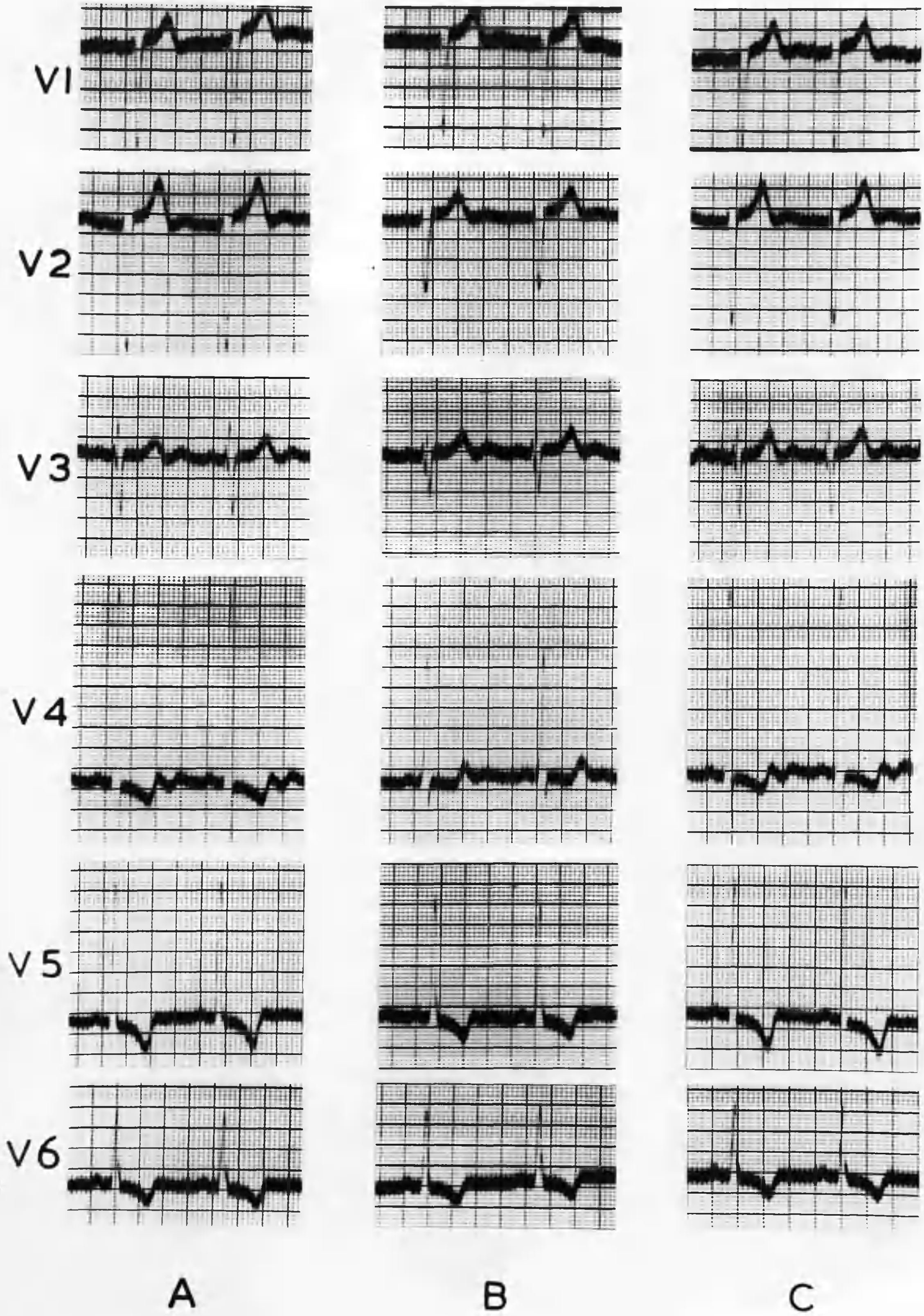
SUMMARY.

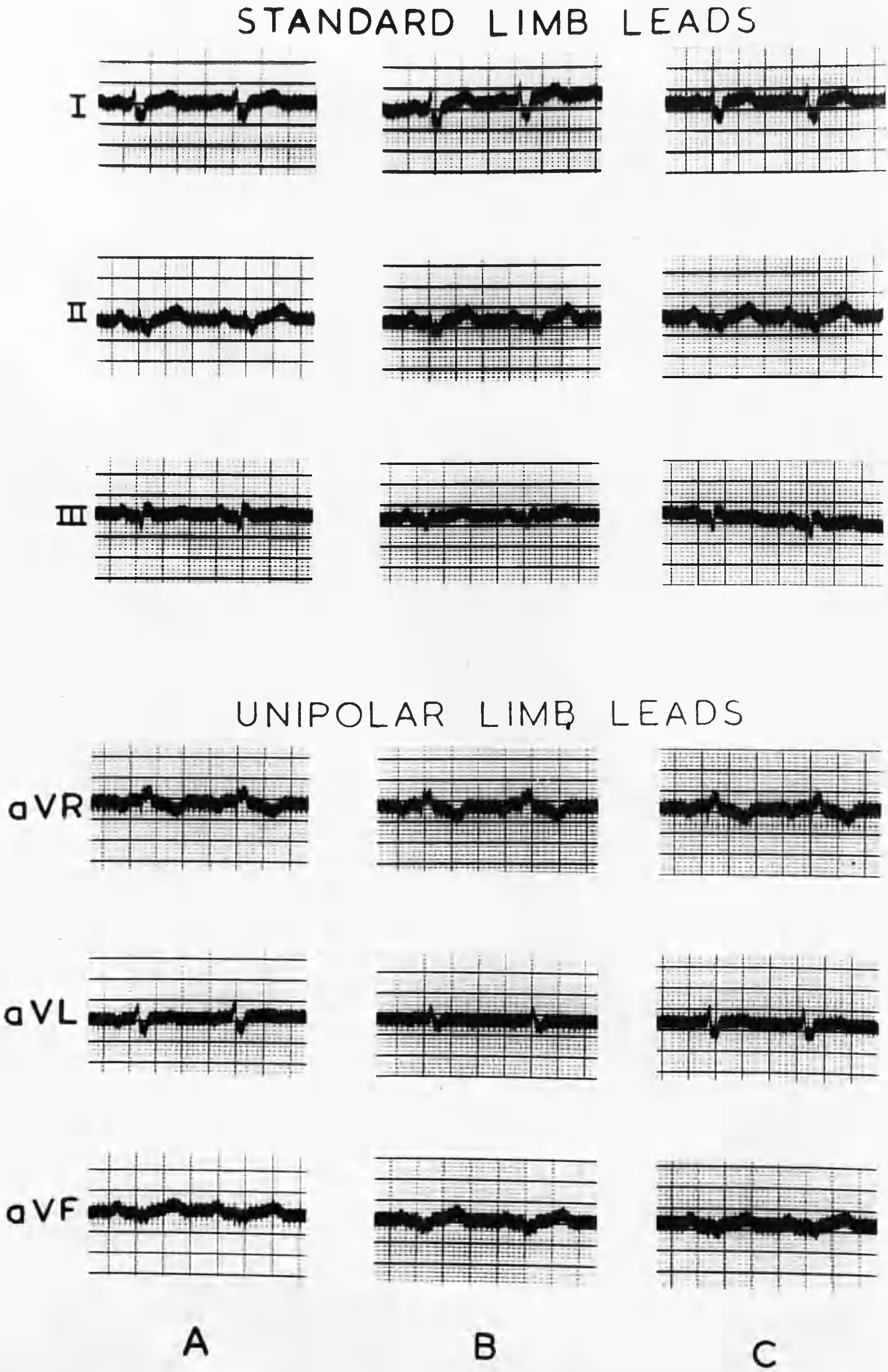
In this case the heart is horizontal with moderate counter-clockwise rotation.

On inspiration the heart becomes less horizontal and undergoes clockwise rotation.

On expiration the heart becomes more horizontal.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 34 PLATE I24a

ABNORMAL. R.R.

Diagnosis: Right Bundle Branch Block. Age 6I years.

STANDARD LIMB LEADS.

A: Control.

Lead I has a broad RS pattern.
Lead II has a broad qRS pattern.
Lead III has a broad rSR' pattern.
All leads have upright P and T waves.

B: Inspiration.

The basic patterns are similar to the control series, but lead I has a taller R and deeper S, lead II has a smaller R and lead III has a smaller S and R' and taller T.

C: Expiration.

All leads are identical with the control series.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has a broad qR pattern and inverted P and T waves. It faces the back of the heart.

aVL has a broad RS pattern and inverted P and low upright T waves. It faces left ventricular surface.

aVF has a broad rsr's' pattern and upright P and T waves. It faces septal region of left ventricle.

The heart is semi-horizontal.

B: Inspiration.

aVR has a smaller q and deeper T.
aVL has a smaller R and S and slightly inverted T.
aVF has a deeper s'.
The heart has become less horizontal.

C: Expiration.

The patterns are similar to those of the control series.

PRECORDIAL LEADS.

A: Control.

VI has a broad notched R pattern.
V2 has an RSR'S' pattern.
V3 has a splintered RS pattern.
V4 has a broad notched RS pattern.
V5 and V6 have broad RS patterns.

The basic pattern is an M-shaped complex the first spike of which represents septal and left ventricular activation and the second spike right ventricular activation. After VI the first spike becomes R and after V2 the second spike is progressively absorbed in the deep S.

T is upright in all leads.

B: Inspiration.

In VI R is taller and the notch is less prominent.

In V2 R is smaller and R' is taller.

In V3 to V6 there is a delay in the absorption of the right ventricular spike in the S wave.

T is slightly diphasic in VI and upright in all other leads.

These differences are due to clockwise rotation.

C: Expiration.

In VI R is smaller and the notch is more prominent.

In V2 R is taller and R' smaller.

In V3 to V6 there is earlier absorption of the right ventricular spike in the S wave.

T is upright in all leads.

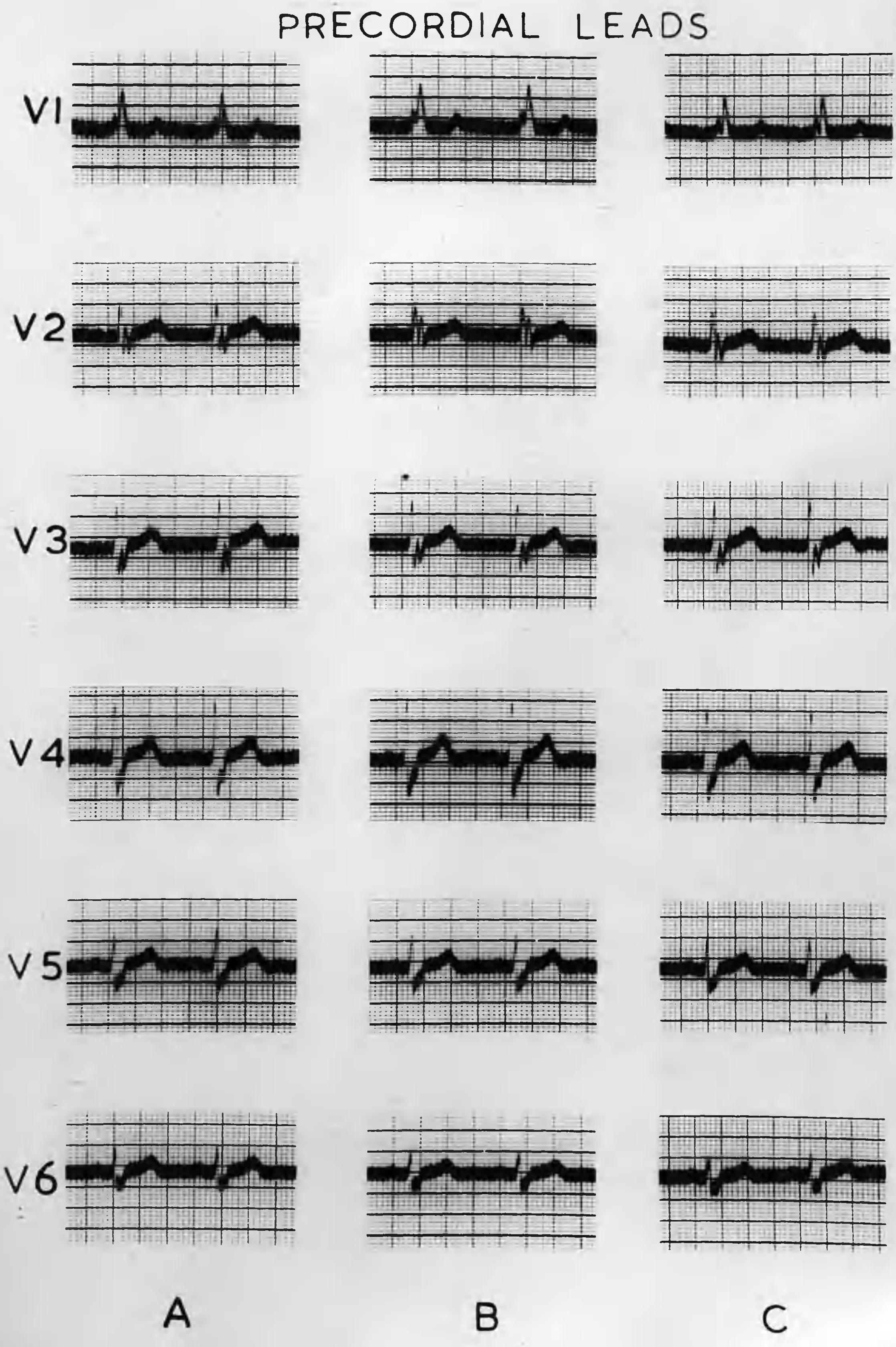
This is due to counter-clockwise rotation.

SUMMARY.

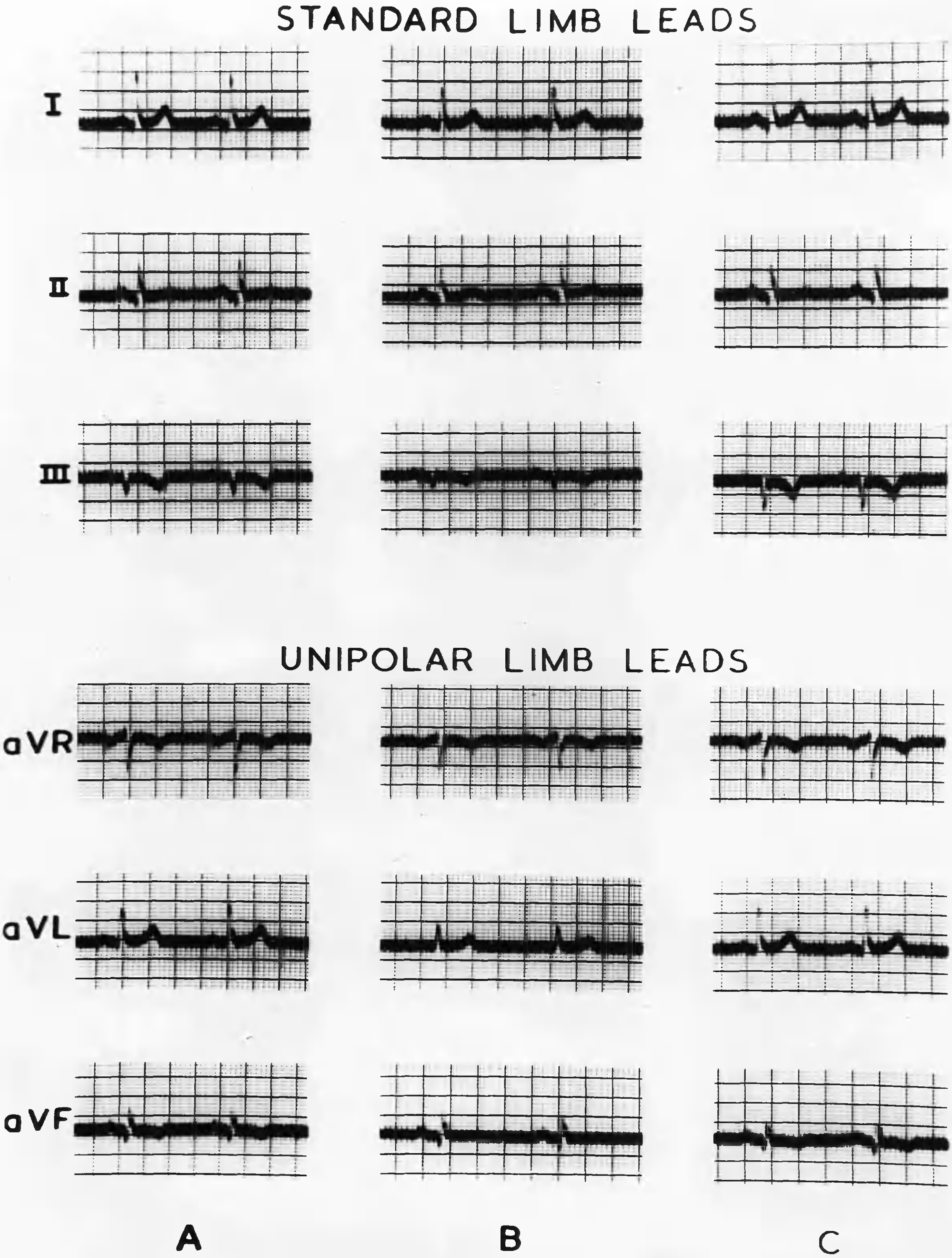
This is a case of right bundle branch block. The heart is semi-horizontal with moderate counter-clockwise rotation.

On inspiration the heart becomes less horizontal and there is clockwise rotation.

On expiration the reverse changes occur.



PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 35 PLATE I25a

ABNORMAL. T.G.

Diagnosis: Posterior Myocardial Infarction(healed). Age 56 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and a qR pattern; the RT segment is slurred and slightly elevated.

Lead II has upright P and low upright T waves and a qR pattern with notched R.

Lead III has upright P and inverted T waves and a splintered QS pattern; the ST segment is slightly depressed.

B: Inspiration.

Lead I shows reduction in R and T; R is still slurred but the RT segment is practically isoelectric.

Lead II shows reduction in R and increase in T.

Lead III shows a much smaller QS pattern and shallow inverted T.

C: Expiration.

Lead I shows increase in P and T and considerable increase in R; the slurring of R is accentuated.

Lead II shows decrease in R; T is practically flat.

Lead III has a deeper QS pattern; the ST segment is shouldered and slightly depressed and T is more deeply inverted.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and an rS pattern. It faces the cavity of the right ventricle.

aVL has upright P and T waves and a qR pattern. It faces the uninjured epicardial surface of the left ventricle.

aVF has upright P and inverted T waves and a QR pattern. It faces the infarcted surface of the left ventricle.

The heart is horizontal with forward rotation of the apex.

B: Inspiration.

aVR shows reduction in S; P and T are less inverted.

aVL shows reduction in P and T and has an R pattern of reduced amplitude. It now tends to face the epicardial surface of the right ventricle.

aVF has flat T waves and a QR pattern with increase in R. It now tends to face the uninjured epicardial surface of the left ventricle.

The heart has become less horizontal and there has been backward rotation of the apex.

C: Expiration.

aVR is similar to the control but has deeper S and more inverted P and T.

aVL is similar to the control but with taller R and T.

aVF is similar to the control but has deeper Q, smaller R and more inverted T.

The heart has become more horizontal but there has also been further forward rotation of the apex so that aVF faces more directly the infarcted surface of the left ventricle.

PRECORDIAL LEADS.

A: Control.

VI has an RS pattern.

V2 to V4 have Rs patterns.

V5 and V6 have qR patterns with slurring of the RT segment.

P and T are upright in all leads.

B: Inspiration.

The patterns are similar to the control series but VI shows reduction in R and S; V2 to V4 have reduction in R and increase in s; V5 and V6 have reduction in q and R.

There has been slight clockwise rotation.

C: Expiration.

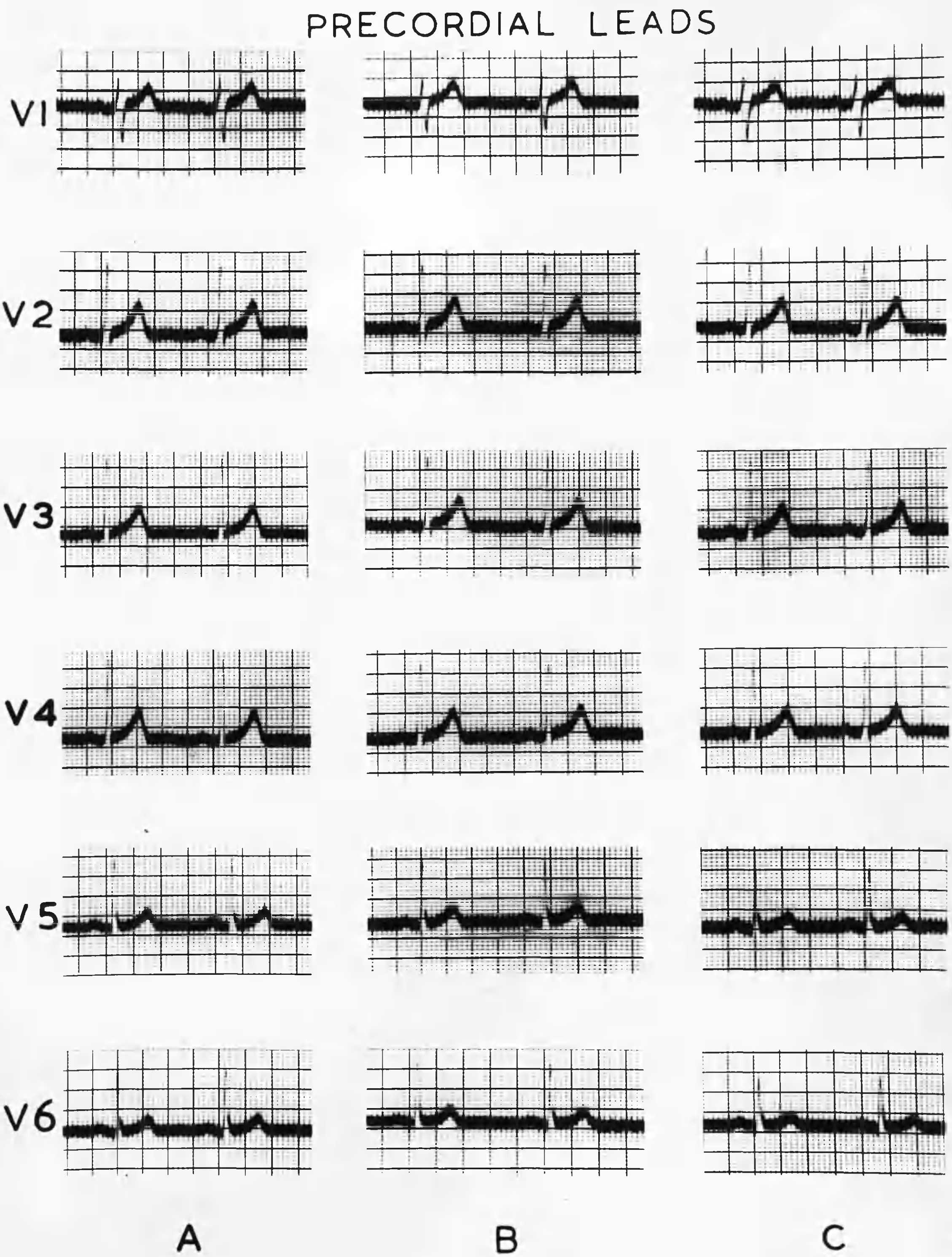
The patterns are identical with the control series apart from reduction of R and T in V5 and V6. This is probably due to the heart becoming more horizontal so that the main muscle mass moves upwards away from these leads.

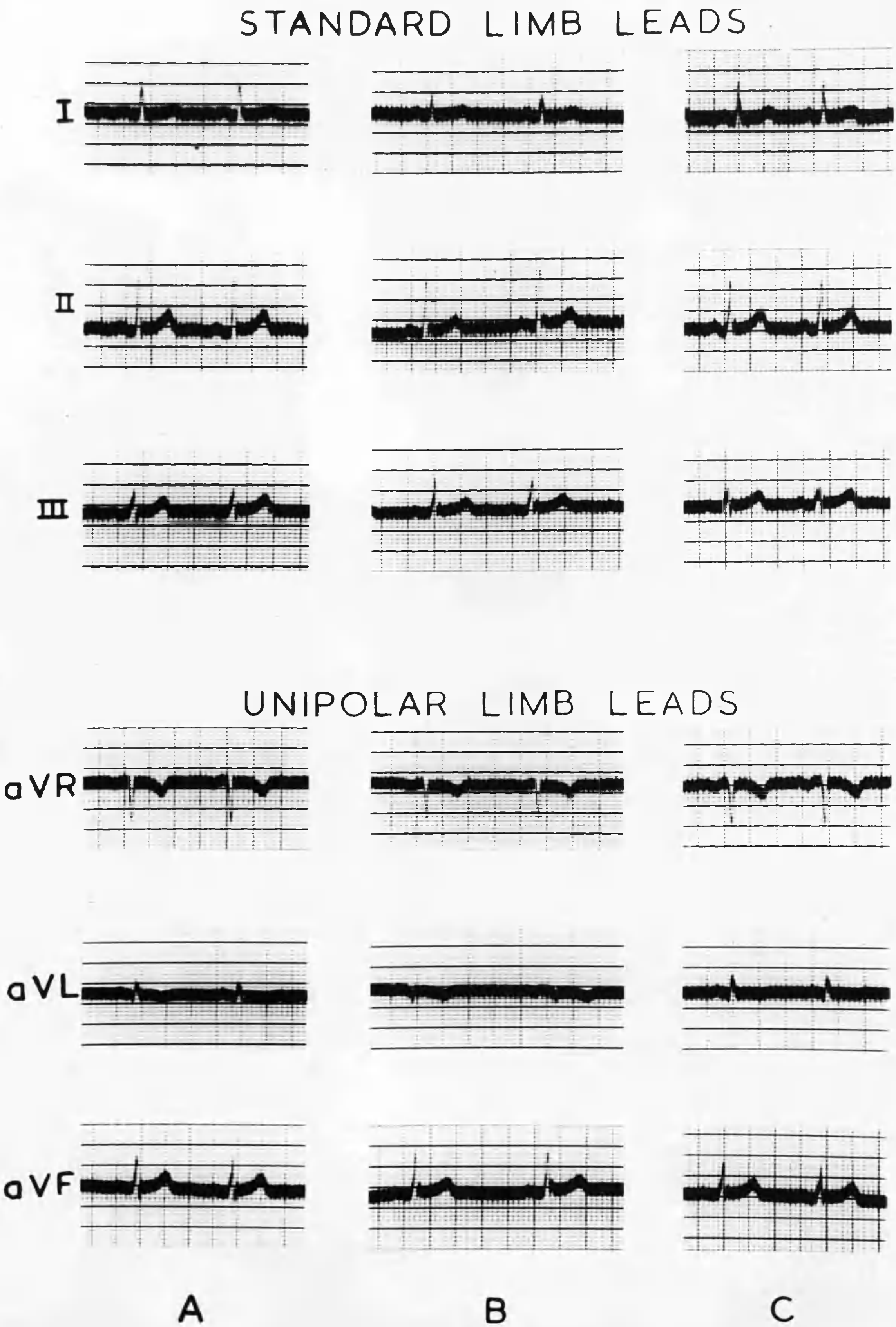
SUMMARY.

In this case of posterior myocardial infarction the heart is horizontal with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes more vertical and undergoes clockwise rotation along with backward rotation of the apex.

On expiration the reverse changes occur.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C


STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 36 PLATE I26a

ABNORMAL. J.J.

Diagnosis: Antero-lateral Myocardial Infarction(healing). Age 42 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and low upright T waves and an R pattern.

Lead II has upright P and T waves and an Rsr' pattern.

Lead III has upright P and T waves and an Rsr' pattern.

There is no axis deviation.

B: Inspiration.

Lead I has an Rs pattern with smaller R.

Lead II has an Rsr' pattern with taller R; T is smaller.

Lead III has an Rsr' pattern with increased R and smaller s; T is reduced.

There has been a shift of the QRS axis to the right.

C: Expiration.

Lead I has an R pattern with increase in R; T is also increased.

Lead II shows an Rsr' pattern with slight reduction in R.

Lead III has an RSr' pattern with reduction in R; T is also reduced.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has upright P and shallow inverted T waves and a qR pattern. It faces part of the epicardial surface of the left ventricle.

aVF has upright P and T waves and an Rsr' pattern. It also faces the epicardial surface of the left ventricle.

The heart is semi-horizontal.

B: Inspiration.

aVR has a smaller QS pattern; T is less inverted.

aVL has inverted P and more deeply inverted T waves and a qs pattern. It now tends to face the cavity of the left ventricle.

aVF still has an Rsr' pattern but with taller R, smaller s and smaller r'; T is reduced.

The heart has become vertical.

C: Expiration.

aVR is similar to the control with deeper T waves.

aVL has upright P and practically flat T waves and a qR pattern with taller R.

aVF is similar to the control but with smaller R.

The heart has become more horizontal.

PRECORDIAL LEADS.

A: Control.

VI to V4 have RS patterns; S-T is elevated and T diphasic.

V5 has an Rs pattern; T is diphasic.

V6 has a qRs pattern; T is upright.

B: Inspiration.

The patterns in V1 to V5 are similar to the control series but the S in V2 to V4 and the R in V5 are smaller. This is probably due to the heart becoming more vertical.

V6 has an Rs pattern with reduction in R. This is evidence of clockwise rotation.

C: Expiration.

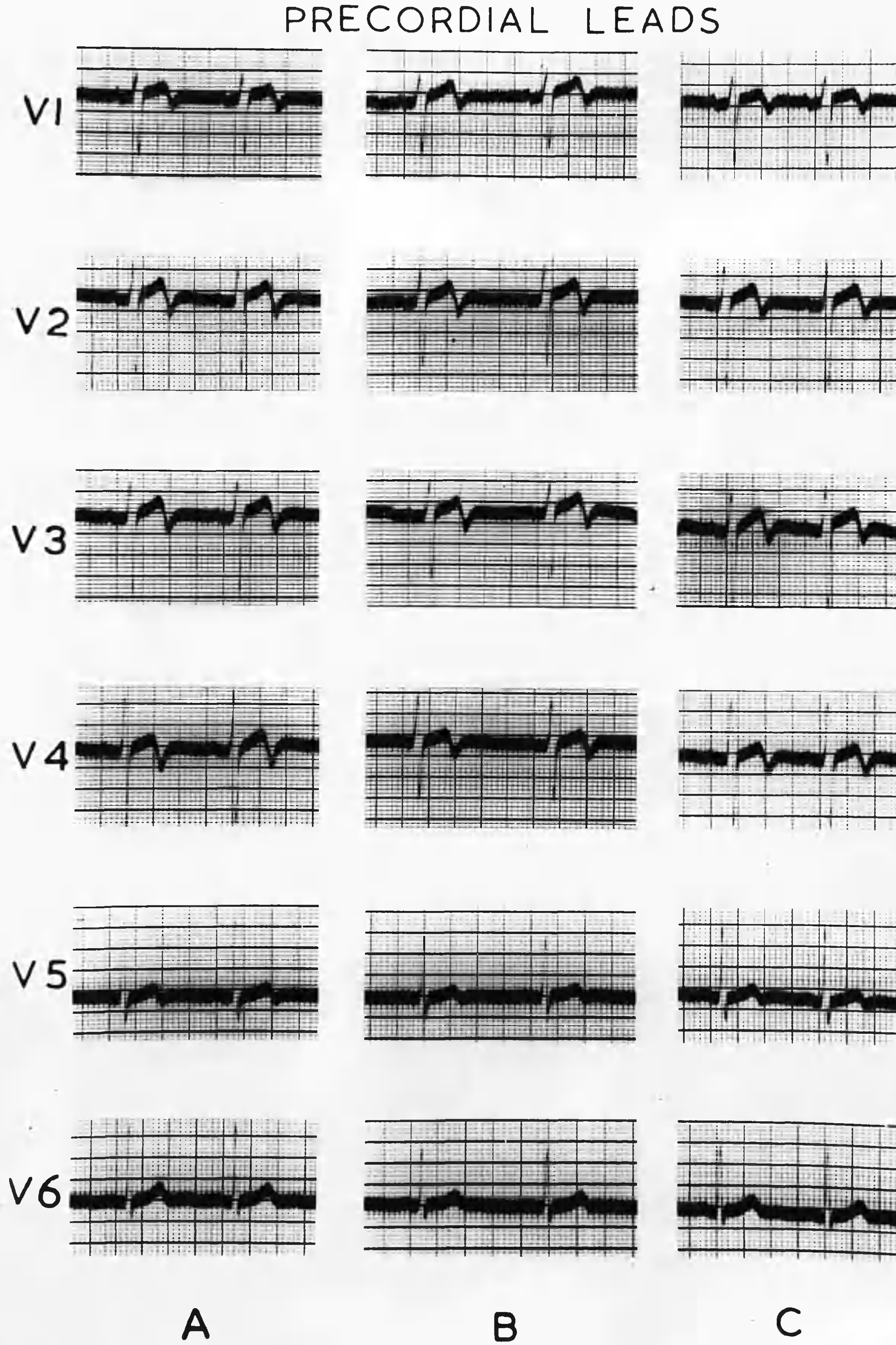
The tracings are identical with the control series apart from some reduction of R in V5 and V6. This could be due to the heart becoming more horizontal and moving upwards away from these precordial positions.

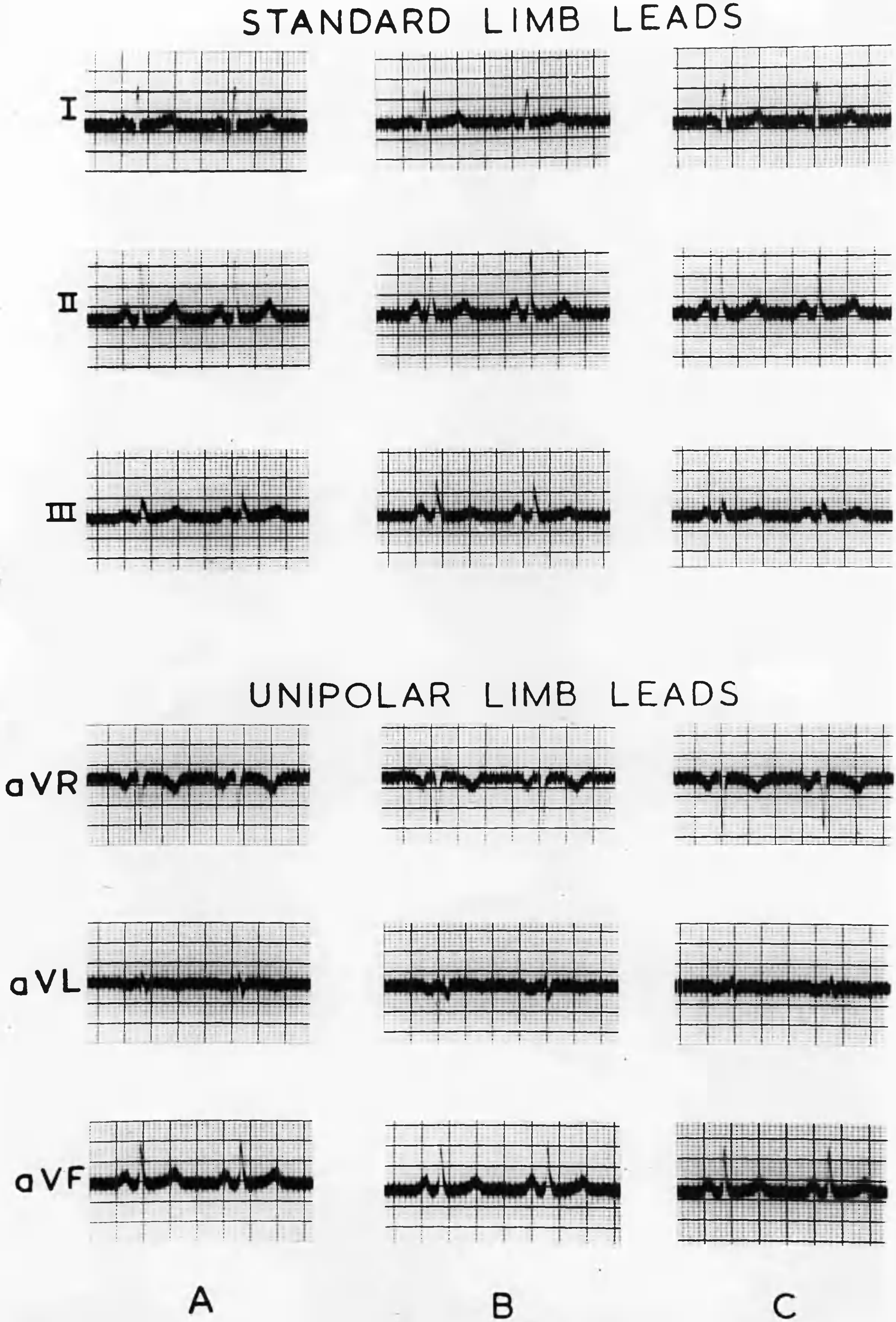
SUMMARY.

This is a case of healed antero-lateral infarction. The heart is semi-horizontal with moderate clockwise rotation and backward rotation of the apex.

On inspiration the heart becomes vertical and there is some clockwise rotation.

On expiration the heart becomes more horizontal.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

ABNORMAL. W.McS.

Diagnosis: Pneumoconiosis. Age 54 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has upright P and T waves and a qRs pattern.

Lead II has tall broad P and upright T waves and an R pattern.

Lead III has broad upright bifid P and upright T waves and an rsR' pattern.

B: Inspiration.

Lead I shows smaller q and R.

Lead II shows taller P.

Lead III shows taller P and smaller T and a splintered R pattern with increased amplitude.

C: Expiration.

Lead I is unchanged.

Lead II shows slight decrease in R.

Lead III shows a splintered rsR' pattern with increase in s and decrease in R'.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has shallow inverted P and T waves and a qRS pattern. It tends to face the epicardial surface of the left ventricle.

aVF has upright P and T waves and an R pattern. It tends to face the epicardial surface of the right ventricle.

The heart is horizontal.

B: Inspiration.

aVR shows a smaller QS and less inverted T.

aVL shows a more inverted P wave and a qrS pattern, with increase in S.

aVF shows slight increase in R and decrease in T.

The heart has become less horizontal.

C: Expiration.

aVR shows less inverted T.

aVL shows a qRs pattern.

aVF shows slight decrease in T.

The heart has become slightly more horizontal.

PRECORDIAL LEADS.

A: Control.

VI has an RS pattern.

V2 to V4 have Rs patterns.

V5 and V6 have qRs patterns.

P is mainly inverted in VI and upright in all other leads.

T is upright in all leads.

B: Inspiration.

The patterns are very similar to those of the control series but q and R are diminished in V5 and V6 and T is also diminished.

The heart has undergone slight clockwise rotation.

C: Expiration.

The patterns are similar to those of the control series but S is decreased in VI and R is increased in V2 and V3.

There has been slight counter-clockwise rotation.

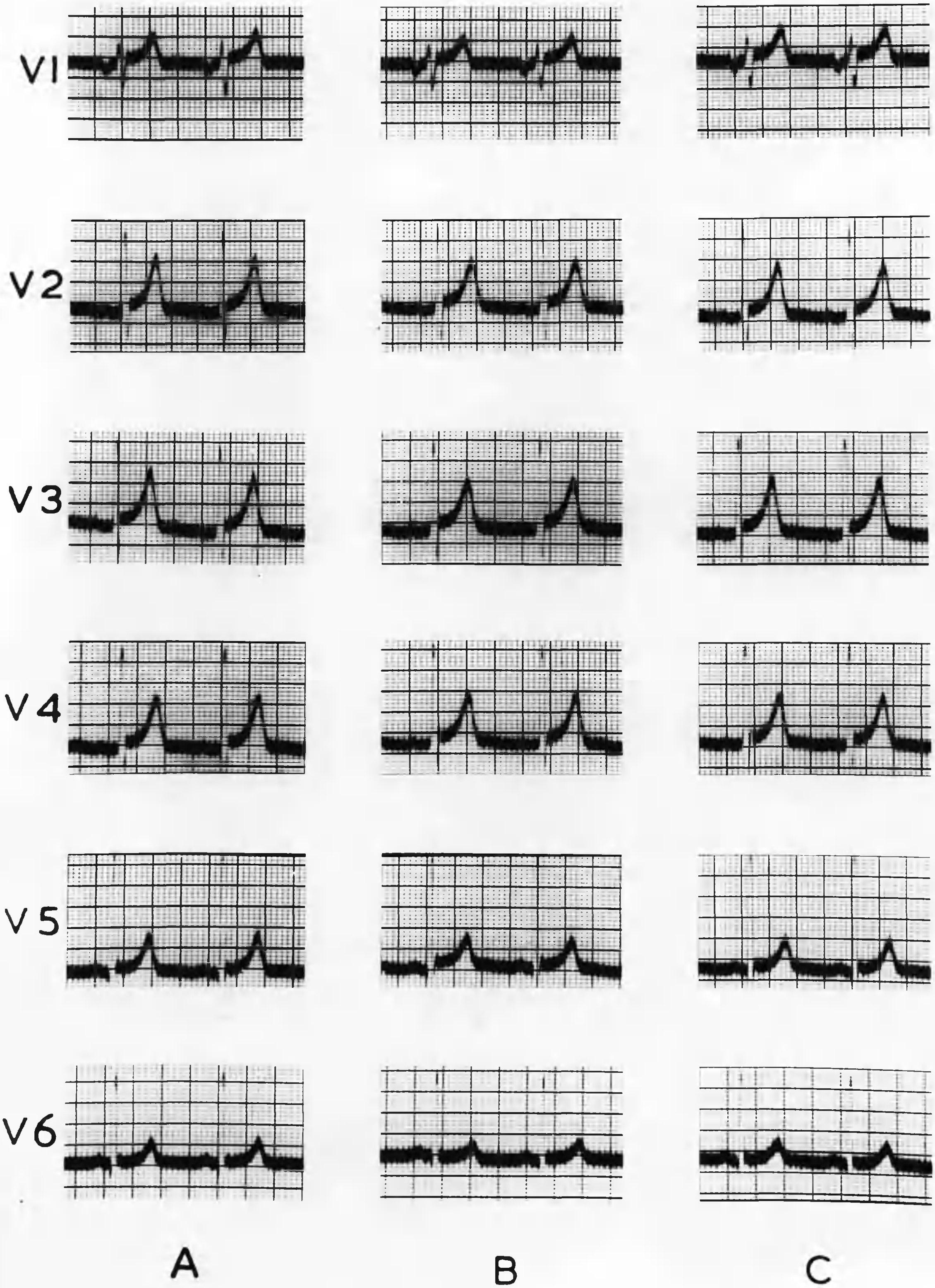
SUMMARY.

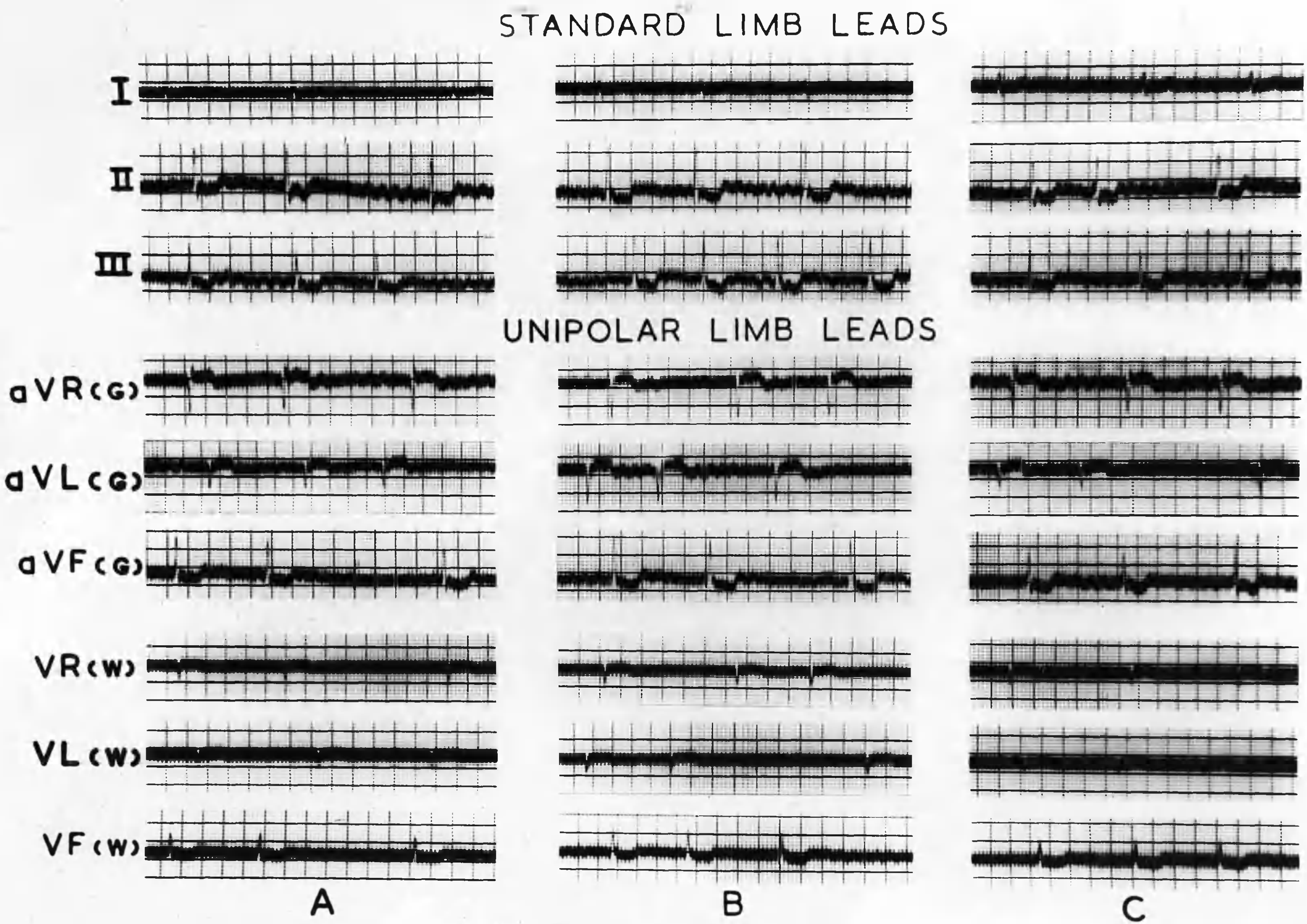
This is a horizontal heart with moderate clockwise rotation and forward rotation of the apex.

On inspiration the heart becomes slightly less horizontal and undergoes slight clockwise rotation.

On expiration the reverse changes occur.

PRECORDIAL LEADS





STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR(G)
aVL(G)
aVF(G)
VR(W)
VL(W)
VF(W)
A
B
C

ABNORMAL. J.H.

Diagnosis: Mitral Stenosis, Auricular Fibrillation and Congestive Heart Failure. Age 38 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has a small Rs pattern and low upright T waves.

Lead II has an Rs pattern; T is diphasic and the ST segment is depressed.

Lead III has an Rs pattern; T is inverted and the ST segment is depressed.

There is auricular fibrillation with possible right ventricular strain and digitalis effect.

B: Inspiration.

Lead I shows a small RS pattern; T is reduced.

Lead II shows an Rs pattern with increase in R and reduction in s; the ST segment is more depressed.

Lead III shows an R pattern of increased amplitude; the RT segment is more depressed and T is more inverted.

There has been a shift of the QRS axis to the right.

C: Expiration.

Lead I shows an Rs pattern with increase in R; T is increased.

Lead II shows an Rs pattern with reduction in R; the ST segment is less depressed.

Lead III shows an Rs pattern with increase in s; the ST segment is less depressed and T is diphasic but mainly negative.

There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has a Qr pattern; the RT segment is elevated and T is diphasic. It faces the back of the heart.

aVL has a Qrs pattern; the ST segment is elevated and T is diphasic. It probably faces the back of the heart.

aVF has an Rs pattern; the ST segment is depressed and T is diphasic. It tends to face the epicardial surface of the right ventricle.

The heart is horizontal with backward rotation of the apex.

B: Inspiration.

aVR has a Qr pattern with increase in Q and reduction in r.

aVL has a QS pattern; the ST segment is more elevated. It now faces the cavity of the left ventricle.

aVF has a qR pattern; the RT segment is more depressed. It now faces the epicardial surface of the left ventricle. The heart has become vertical.

C: Expiration.

The patterns are similar to the control series but aVL shows decrease in Q and increase in r while aVF shows decrease in R and increase in s.

The heart has become more horizontal.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are more difficult to determine.

PRECORDIAL LEADS.

A: Control

VI to V4 have rS patterns; T is probably flat in VI to V3 and diphasic in V4; the ST segment is slightly depressed in V4.

V5 and V6 have qR patterns; the RT segment is depressed and T is diphasic but mainly negative.

B: Inspiration.

VI to V4 have patterns similar to the control series.

V5 has a qRs pattern with reduction in q and R; the ST segment is less depressed.

V6 has a qR pattern with reduction in q and R; the RT segment is less depressed.

There has been clockwise rotation of the heart.

C: Expiration.

VI to V3 have patterns similar to the control series.

V4 has an RS pattern with reduction in S; the ST segment is more depressed.

V5 and V6 are similar to the control series.

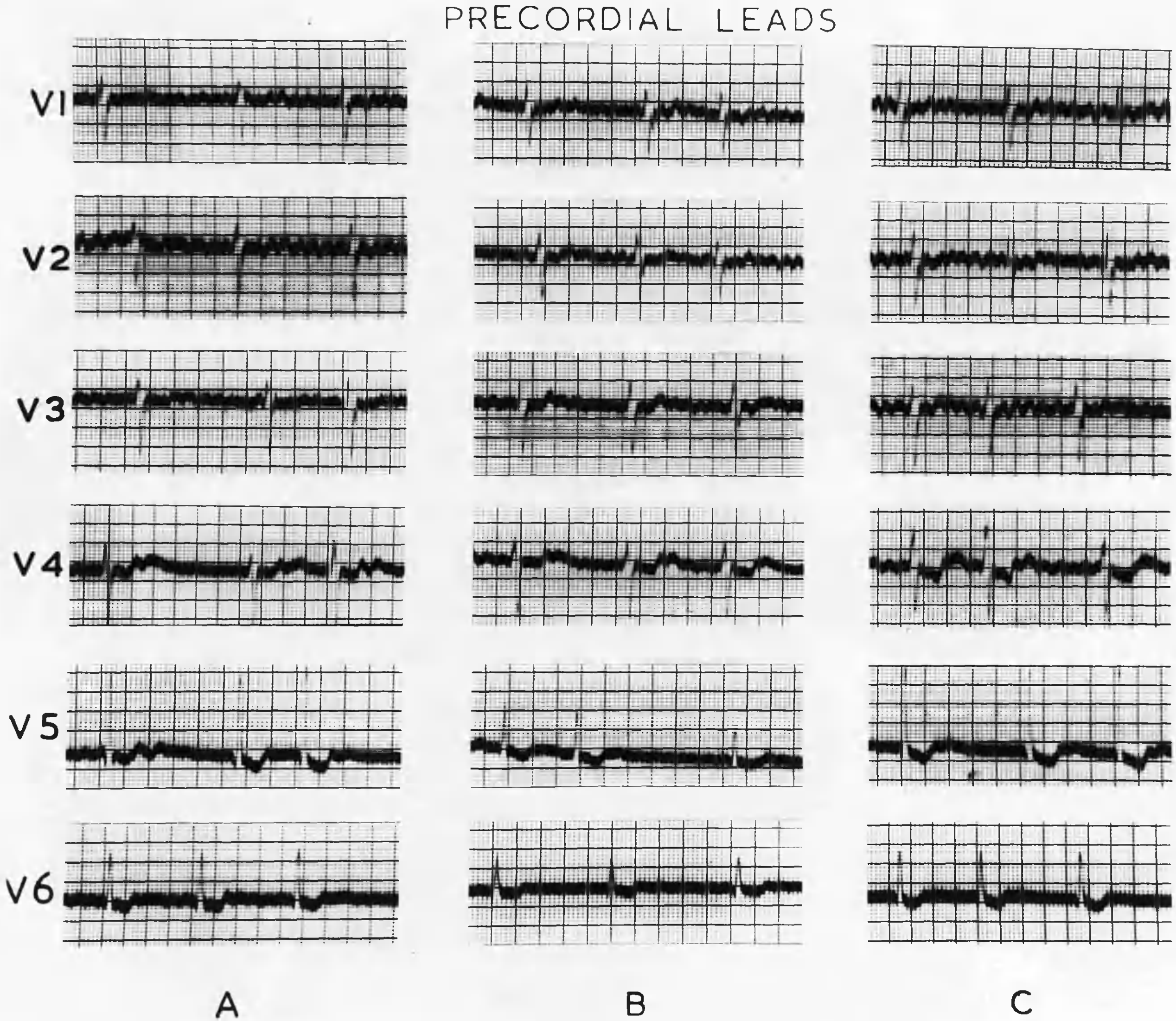
There has been counter-clockwise rotation of the heart.

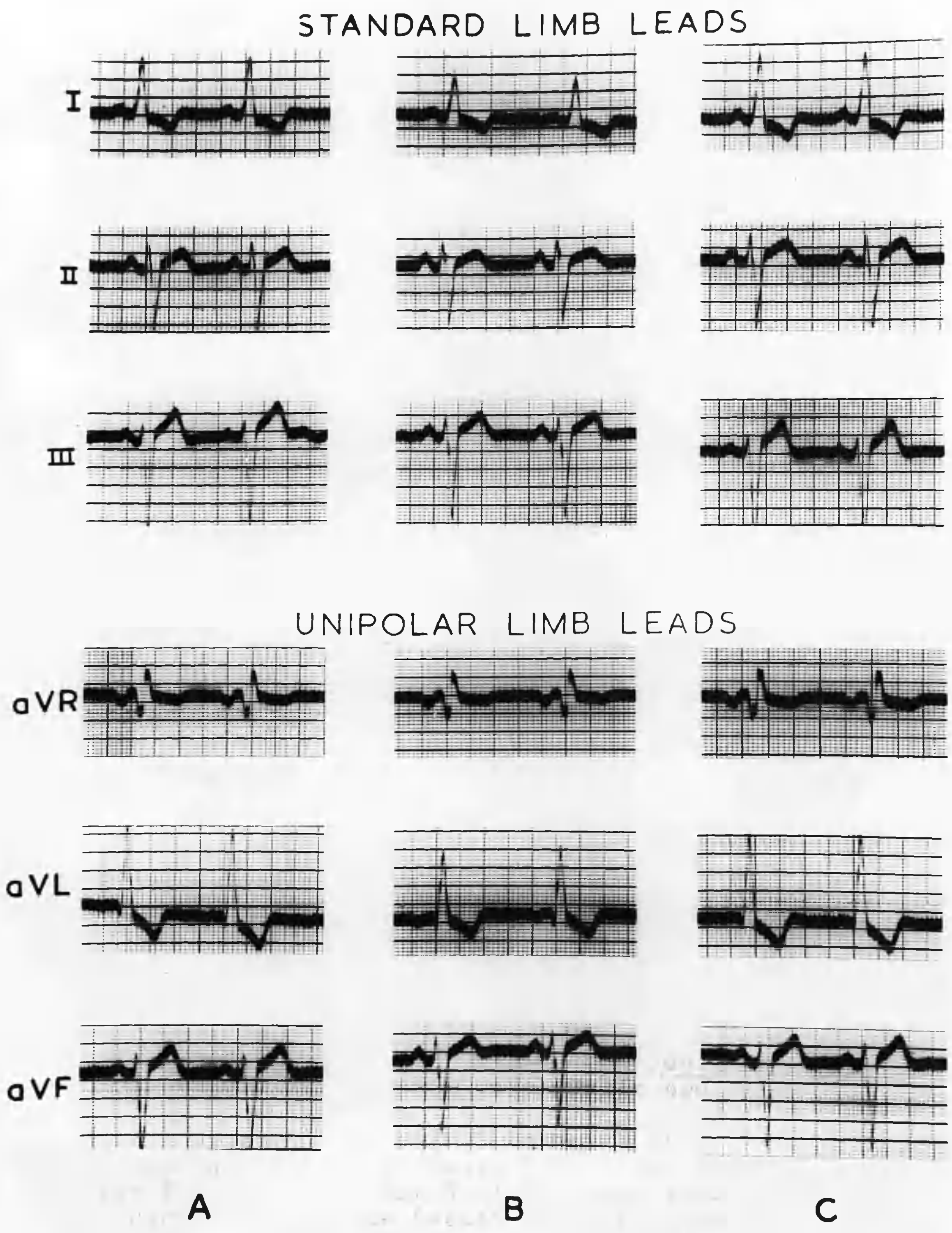
SUMMARY.

In this case the heart is horizontal with moderate clockwise rotation and backward rotation of the apex.

On inspiration the heart becomes vertical and undergoes further clockwise rotation.

On expiration slight counter-clockwise rotation occurs.


PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C



STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

ABNORMAL. J.T.

Diagnosis: Left Bundle Branch Block. Age 47 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has a wide R pattern; P is upright, T is inverted and the RT segment is depressed.

Leads II and III have wide rS patterns; P and T are upright and the ST segment is elevated.

B: Inspiration.

Lead I shows reduction in P and R; T is less inverted. The RT segment is less depressed.

Lead II shows increase in P and reduction in r,S and T. The ST segment is less elevated.

Lead III shows increase in P and r and reduction in S and T. The ST segment is less elevated.

C: Expiration.

Lead I shows increase in R and T is more inverted.
Lead II shows increase in S and T.
Lead III shows increase in S and T.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and shallow inverted T waves and a broad QR pattern. It probably faces the back of the heart.

aVL has diphasic P and deeply inverted T waves and a broad qR pattern. It probably faces the epicardial surface of the left ventricle. The RT segment is depressed.

aVF has upright P and T waves and a broad rS pattern. The ST segment is elevated. It probably faces the epicardial surface of the right ventricle.

The heart is horizontal, with backward rotation of the apex.

B: Inspiration.

aVR shows slight decrease in Q and increase in R.

aVL has an inverted P and less inverted T waves. R is reduced and the RT segment is less depressed.

aVF shows increase in P and decrease in T waves. r is increased, S is decreased and the ST segment is less elevated.

The heart has become less horizontal.

C: Expiration.

aVR shows deeper P and T waves; the RT segment is slightly depressed.

aVL is unchanged.

aVF is unchanged.

PRECORDIAL LEADS.

A: Control

V1 has a broad QS pattern; P is diphasic, T is upright and the ST segment elevated.

V2 has a broad splintered rS pattern; P and T are upright and the ST segment is elevated.

V3 has a broad rSr'S' pattern; P and T are upright and the ST segment is elevated.

V4 has a broad splintered RS pattern; P and T are upright and the ST segment is slightly elevated.

V5 has a broad RS pattern; P is upright, T is diphasic but mainly negative and the ST segment is depressed.

V6 has a broad RS pattern; P is upright, T is inverted and the ST segment is depressed.

B: Inspiration.

V1 shows a broad rS pattern with reduction in S.

V2 shows a broad rSR's' pattern with reduction in S; T is reduced.

V3 shows a broad rsR's' pattern; T is reduced and the ST segment is less elevated.

V4 has a broad splintered Rs pattern; T is diphasic; the ST segment is slightly depressed.

V5 has a broad Rs pattern; T is diphasic but mainly negative and the ST segment is depressed.

V6 has a broad R pattern with slight reduction in amplitude.

These changes are difficult to explain but if the R' in V2 and V3 is of right ventricular origin and the s' is of left ventricular origin then they could be accounted for by clockwise rotation of the heart with backward rotation of the apex.

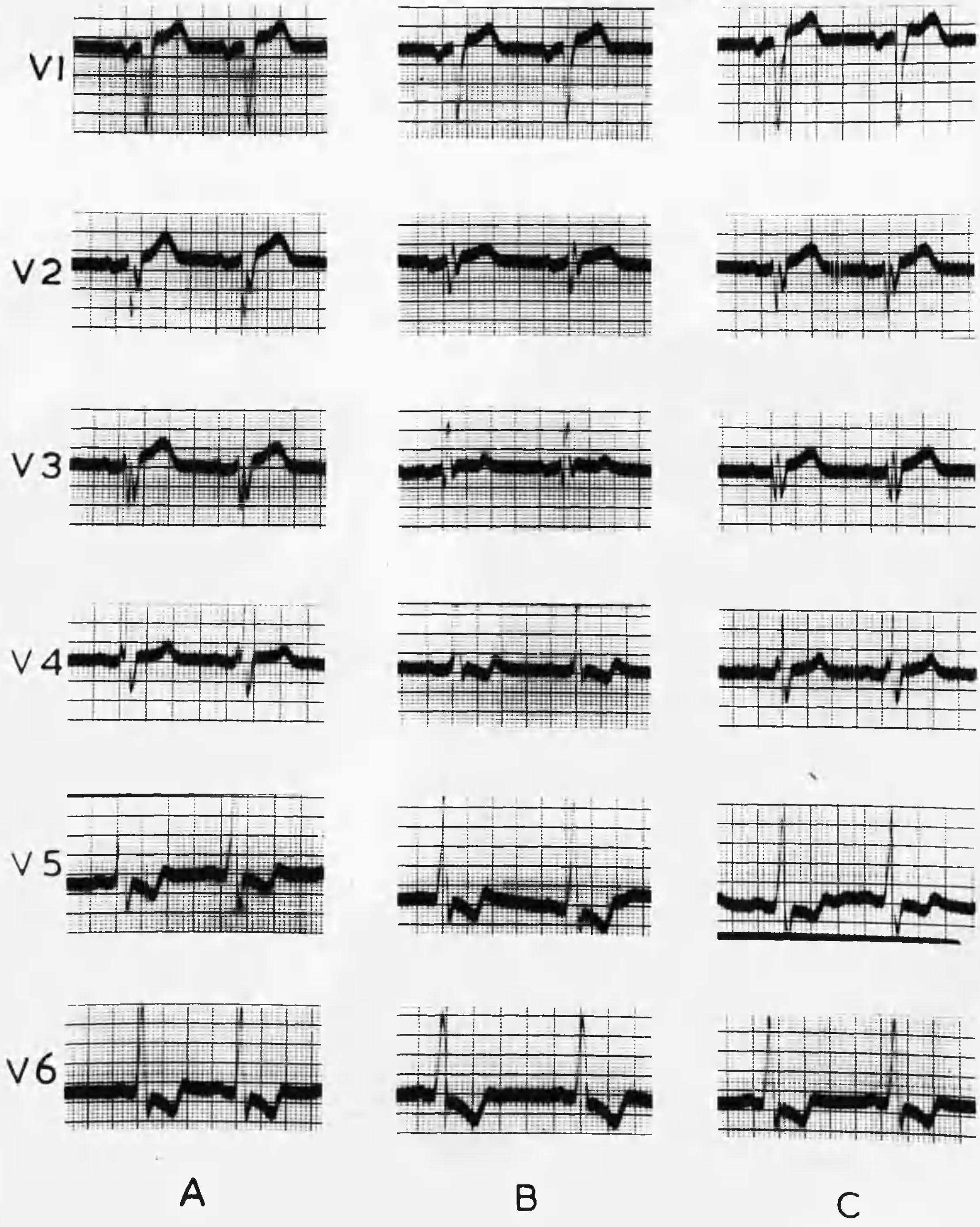
The reduction of T and of the ST elevation in V2 to V4 might be attributed to a lessening of the negative left ventricular effect.

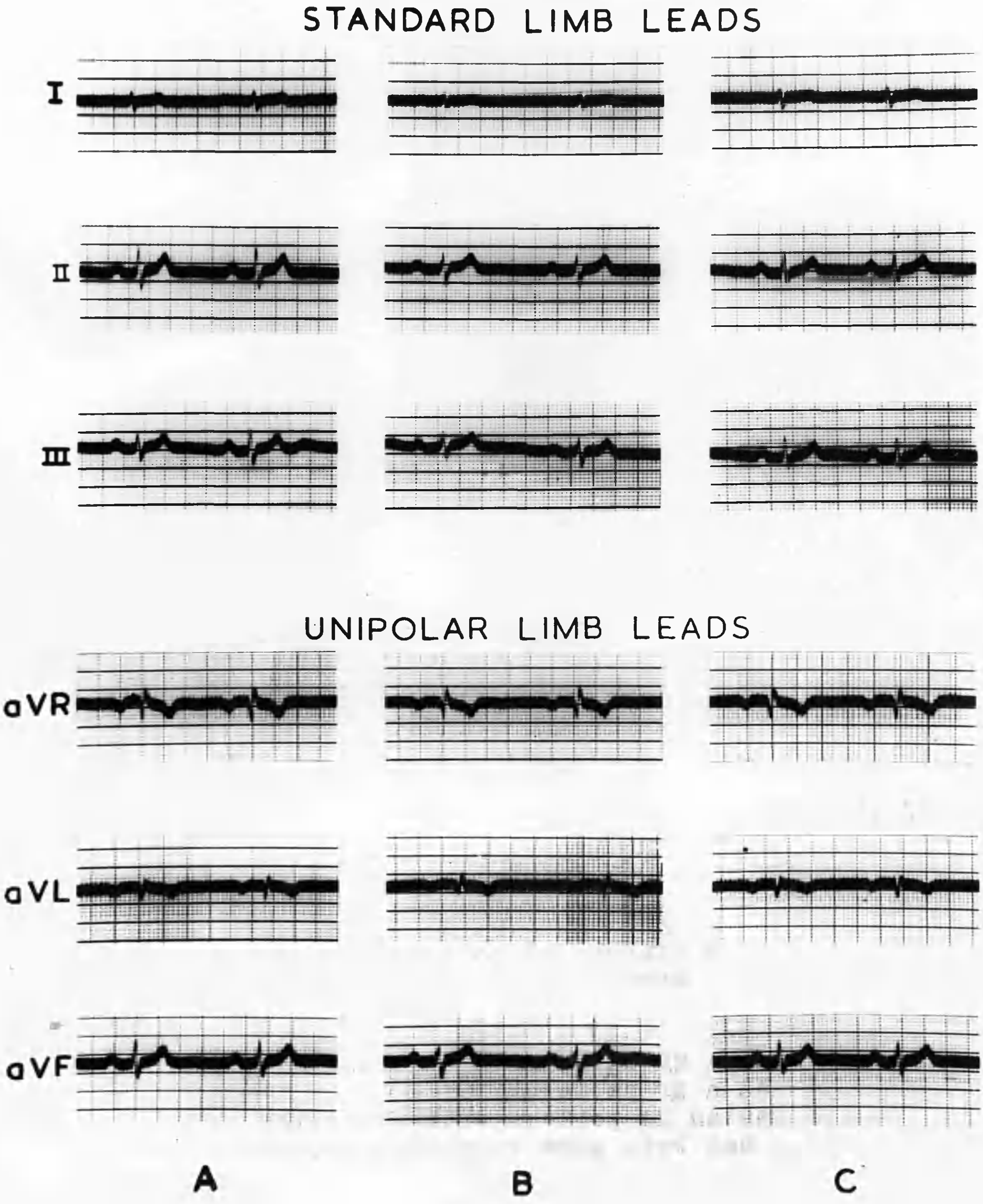
C: Expiration.

The patterns are very similar to the control series apart from slight reduction of S and increase of r' in V2 and V3.

This is a horizontal heart probably with marked clockwise rotation and backward rotation of the apex.

PRECORDIAL LEADS




STANDARD LIMB LEADS
I
II
III
UNIPOLAR LIMB LEADS
aVR
aVL
aVF
A
B
C

CASE NO. 40

ABNORMAL. J.D.

Diagnosis: Chronic Bronchitis. Age 40 years.

STANDARD LIMB LEADS.

A: Control.

Lead I has flat P and low upright T waves and a small RS pattern.

Leads II and III have upright P and T waves and an RS pattern.

B: Inspiration.

Lead I has an rs pattern; T is slightly reduced.

Leads II and III show reduction in P and T and RS patterns with reduction in R.

C: Expiration.

Lead I is similar to the control.

Lead II has an Rs pattern with reduction in R.

Lead III has an Rs pattern.

UNIPOLAR LIMB LEADS.

A: Control.

aVR has inverted P and T waves and a QR pattern. It faces the back of the heart.

aVL has inverted P and T waves and a QR pattern. It also faces the back of the heart.

aVF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal with backward rotation of the apex.

B: Inspiration.

aVR is unaltered.

aVL has a QR pattern with increase in R.

aVF has a slurred RS pattern.

There has been clockwise rotation.

C: Expiration.

aVR has a QR pattern with reduction in R.

aVL has a Qr pattern.

aVF has an Rs pattern with reduction in s.

There has been some counter-clockwise rotation.

PRECORDIAL LEADS.

A: Control.

VI to V5 have rS patterns.
V6 has an RS pattern.
P and T are upright in all leads.

B: Inspiration.

VI to V5 have rS patterns with reduction of S in VI and V2.

V6 has an RS pattern with reduction in R and increase in S.

There has been some clockwise rotation;

C: Expiration.

The patterns are identical with the control series.

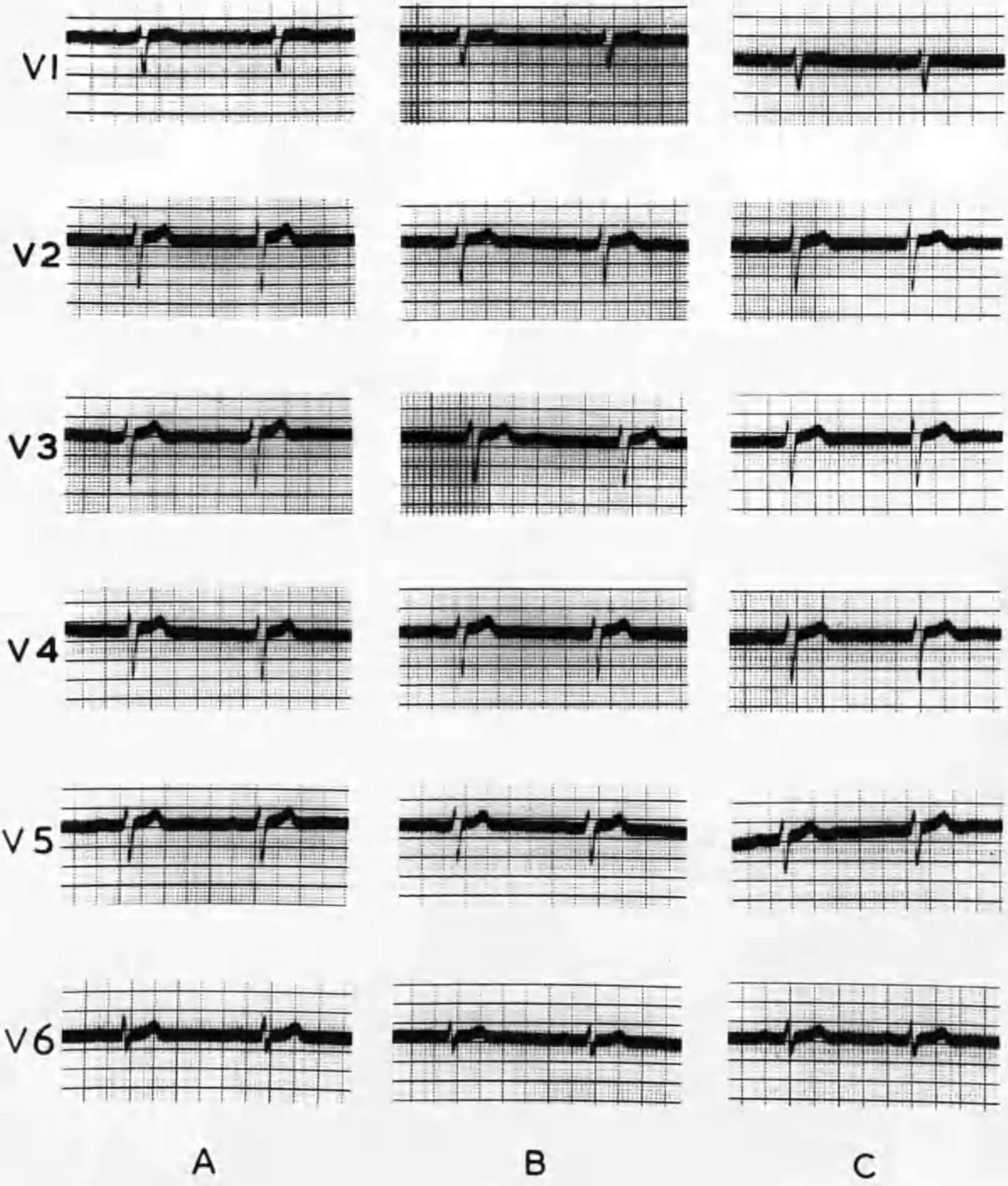
SUMMARY.

This is a horizontal heart with marked clockwise rotation and backward rotation of the apex.

On inspiration the heart undergoes further clockwise rotation.

On expiration there is slight counter-clockwise rotation.

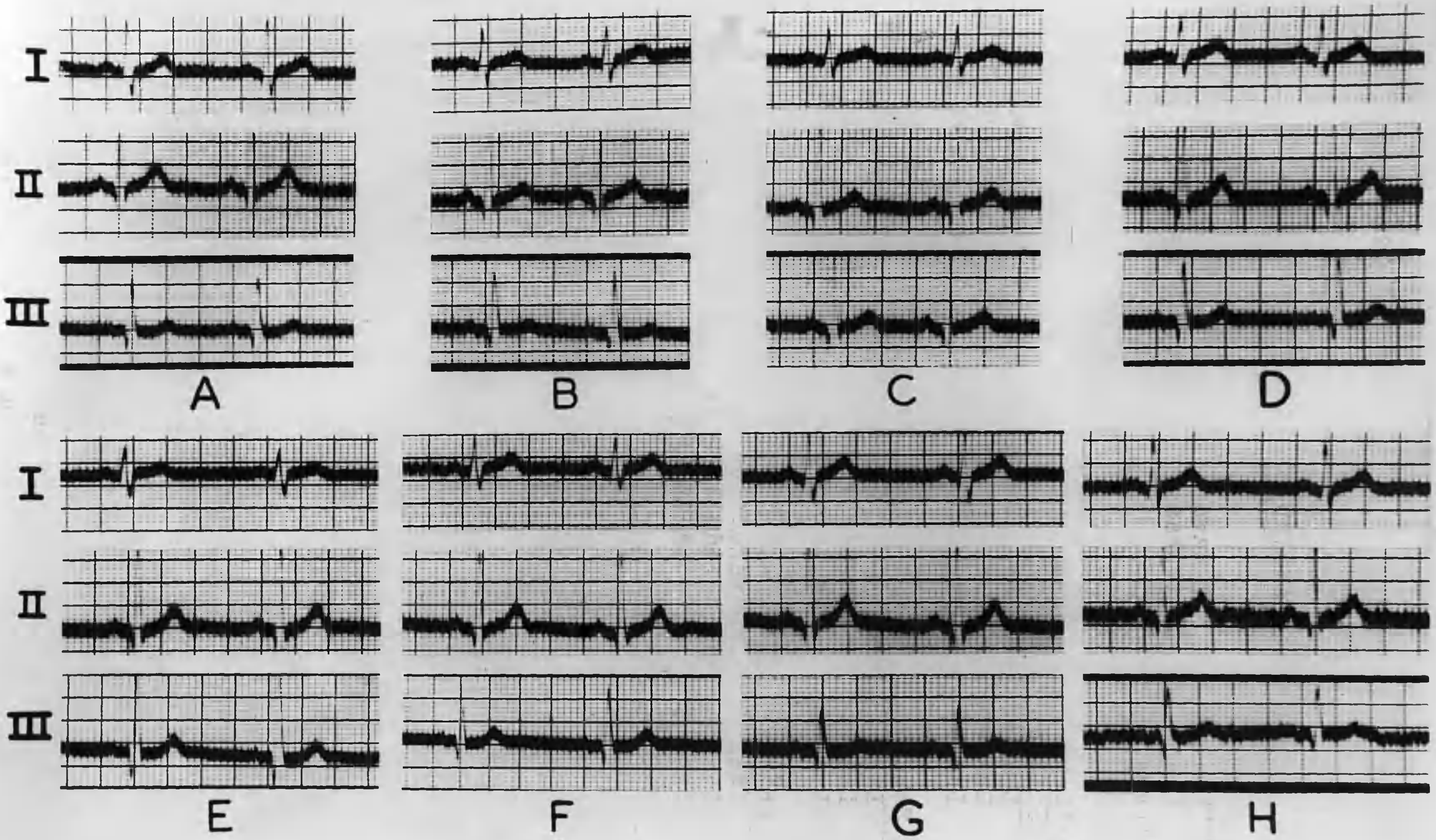
PRECORDIAL LEADS



STUDIES IN ELECTROCARDIOGRAPHY

APPENDIX C

STANDARD LIMB LEADS



CASE NO. I   PLATE 13Ia

NORMAL.   G.J.

Age 30 years.

STANDARD LIMB LEADS.

D: Supine.

Leads I and II have upright P and T waves and qRs patterns.

Lead III has diphasic P and upright T waves and a qR pattern.

Vertical Rotation.

A: Sitting.

Lead I shows increase in R and s; T is increased.
Lead II shows reduction in q; T is increased.
Lead III shows reduction in q and R; T is reduced.

B: Standing.

Lead I shows reduction in R and increase in s; T is reduced.
Lead II shows reduction in q; T is reduced.
Lead III shows reduction in q; T is reduced.

C: 45° head up.

Lead I shows reduction in R; T is reduced.
Lead II shows reduction in q; T is reduced.
Lead III shows reduction in q and increase in R.

In B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in R; T is increased.
Lead II shows reduction in R; T is increased.
Lead III shows reduction in R.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

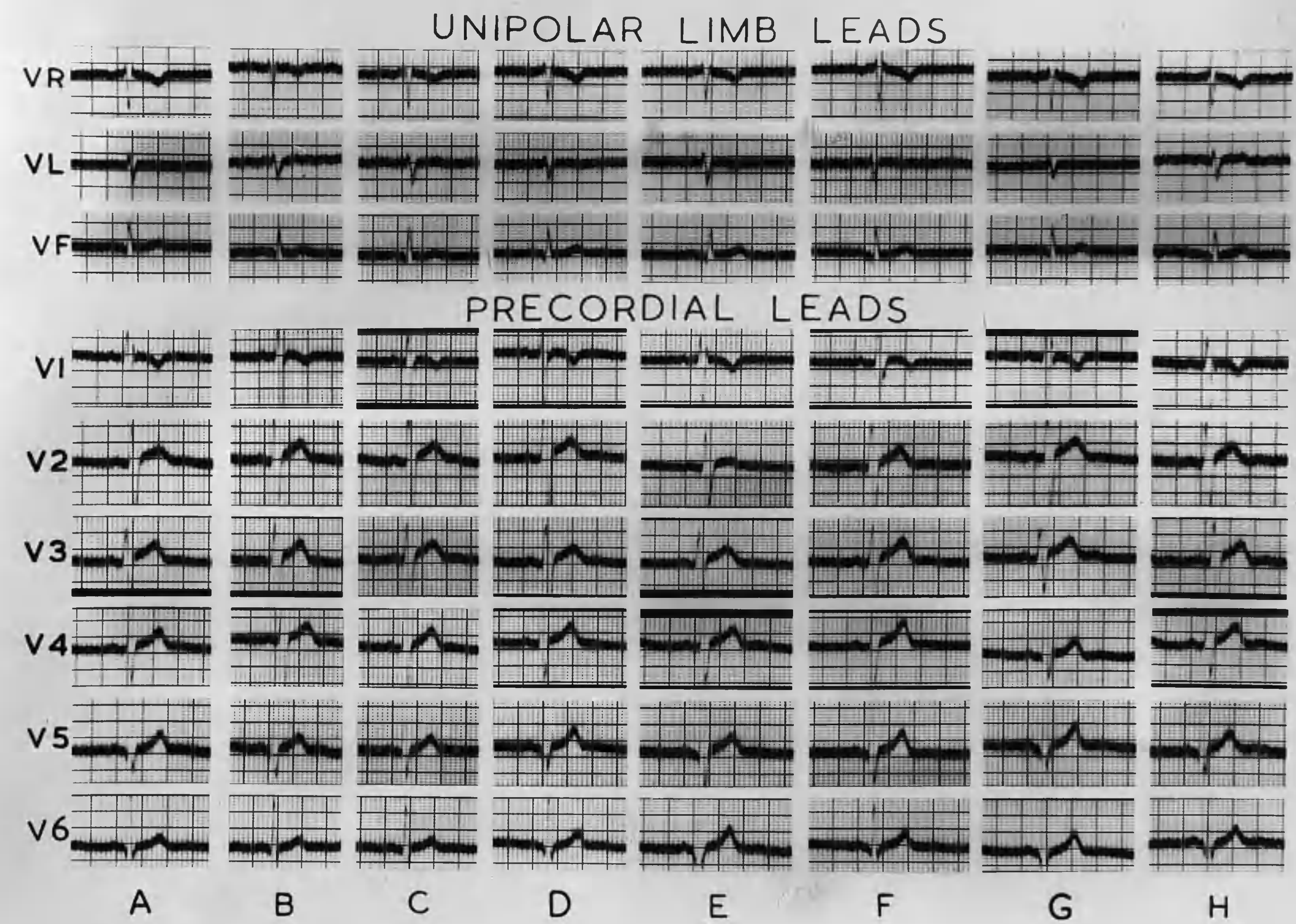
Lead I has an RS pattern with reduction in R; T is reduced.
Lead II shows increase in R; T is increased.
Lead III shows increase in q and R; T is increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead II shows increase in s; T is increased.
Lead III has a qRs pattern with decrease in R; T is increased.

G: Prone.

Lead I shows increase in R and s; T is increased.
Lead II shows increase in s; T is increased.
Lead III shows reduction in R; T is reduced.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
VI
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

CASE NO. I (contd.)

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

VL has shallow inverted P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows increase in S and r'.
VL shows increase in r and S; T is flat.
VF shows reduction in q and R; T is reduced.

B: Standing.

VR shows reduction in S; T is less inverted.
VL shows increase in S; T is flat.
VF shows reduction in R; T is reduced.

C: 45° head up.

VR shows less deeply inverted T.
VL shows increase in S; T is flat.
VF shows reduction in T.

In A,B and C the heart has become more vertical.

H: 45° head down.

VL shows increase in r and S; T is upright.
VF has a qRs pattern.

Horizontal Rotation.

E: Left Lateral.

VL shows increase in r and S; T is slightly inverted.

F: Right Lateral.

VR shows increase in S and r'; T is more deeply inverted.
VL shows increase in r and S.
VF shows increase in T and has a qRs pattern.

G: Prone.

VR shows increase in S; T is mpre deeply inverted.
VL shows reduction in S; P and T are flat.
VF shows reduction in R.
The heart has become less vertical.

PRECORDIAL LEADS.

D: Supine.

VI has an rSr's' pattern; P is upright and T is inverted.

V2 and V3 have rS patterns; P and T are upright.

V4 to V6 have qRs patterns; P and T are upright.

There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control but r' is increased in VI.

B: Standing.

VI to V3 have rS patterns.

V4 has an RS pattern.

V5 and V6 have qRs patterns with increase in s.

T is reduced in V4 to V6.

C: 45° head up.

The patterns are similar to those in B.

In B and C there has been clockwise rotation.

H: 45° head down.

VI to V3 are similar to the control.

V4 has an Rs pattern.

V5 and V6 have qRs patterns with increase in q and R.

The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI has an rSr's' pattern with reduction in r and S and increase in r'; T is more inverted.

V2 and V3 have rS patterns with reduction in r; T is reduced in V2.

V4 to V6 have qRs patterns with increase in q,R and s; T is increased in V6.

Displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

VI to V3 have rS patterns.

V4 to V6 have qRs patterns with reduction in q and R; s is increased in V4 and V5.

T is less inverted in VI, increased in V2 to V4.

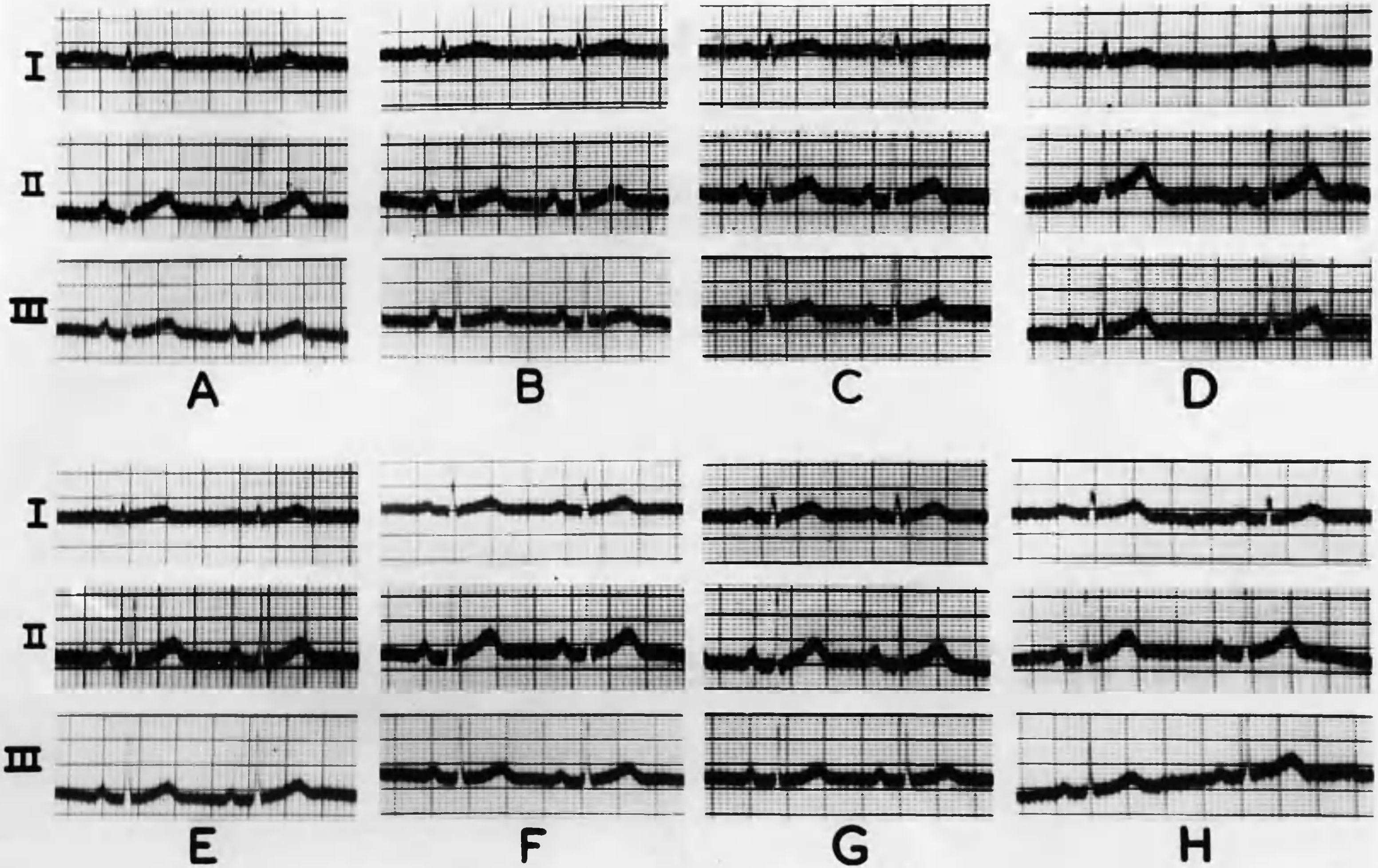
Displacement to the right has occurred.

G: Prone.

VI has an rSr's' pattern with increase in r'.

V2 has an rS pattern. V3 has an RS pattern. V4 to V6 have qRs patterns with increase in q and R. T is deeper in VI and increased in V[illegible] and V[illegible].

STANDARD LIMB LEADS



NORMAL.

R.R.

Age 24 years.

STANDARD LIMB LEADS.

D: Supine.
Leads I and II have upright P and T waves and qRs patterns.
Lead III has upright P and T waves and an Rs pattern.

Vertical Rotation.

A: Sitting.
Lead I shows increase in s.
Lead II shows increase in P; T is reduced.
Lead III shows increase in P and R; T is reduced.

B: Standing.
Lead I shows increase in s.
Lead II shows increase in P; T is reduced.
Lead III has a qR pattern; P is increased; T is reduced.

C: 45° head up.
The changes are similar to those in B.

In A, B and C there has been a shift of the QRS axis to the right.

H: 45° head down.
Lead I shows increase in R and T.
Leads II and III show reduction in T.
There has been a shift of the QRS axis to the left.

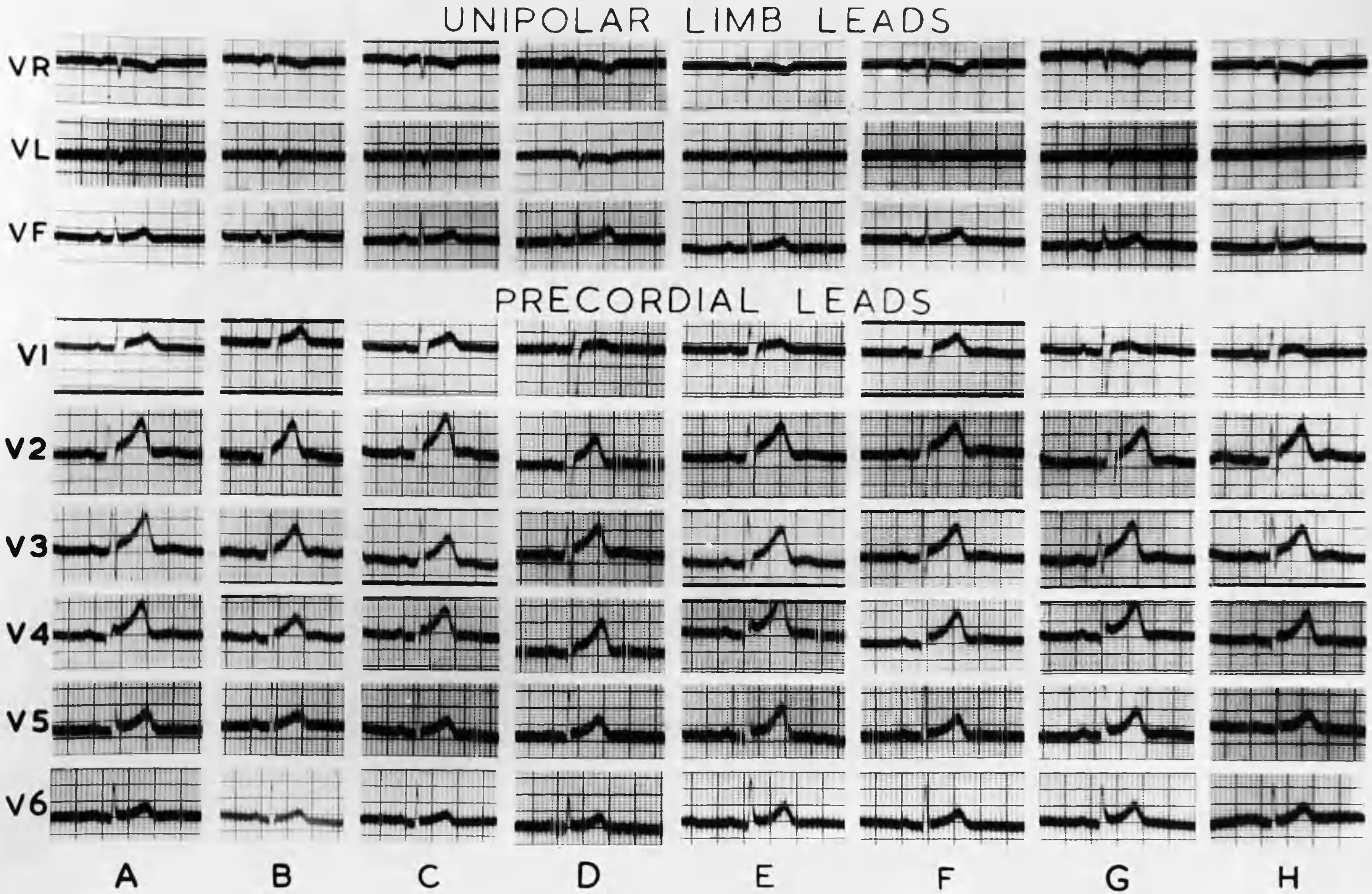
Horizontal Rotation.

E: Left Lateral.
Lead I shows reduction in R.
Lead II shows reduction in T.
Lead III shows increase in R; T is reduced.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead I shows increase in q and R; T is increased.
Lead II shows increase in P; T is reduced.
Lead III shows reduction in T.
There has been a shift of the QRS axis to the left.

G: Prone.
Lead I shows increase in R, s and T.
Lead II shows increase in P; T is reduced.
Lead III has a qR pattern with reduction in R; P is increased; T is reduced.

There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
V1
V2
V3
V4
V5
V6
A
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H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VL has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VF has upright P and T waves and an R pattern. It probably faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VL shows a smaller QS; T is flat.

VF shows reduction in R and T.

B: Standing.

VR has a Qr pattern; T is less inverted. It faces the back of the heart.

VL has a smaller QS; T is flat.

VF shows a qRs pattern; T is reduced. It faces the epicardial surface of the left ventricle.

The heart has become more vertical.

C: 45° head up.

The patterns are similar to those in B.

H: 45° head down.

VL has a smaller QS; P and T are flat.

VF shows reduction in R and T.

The heart has probably become less vertical.

Horizontal Rotation.

E: Left Lateral.

VR has a smaller QS; T is less inverted.

VL has a smaller QS; T is less inverted.

VF shows reduction in T.

F: Right Lateral.

VL has a smaller QS; P and T are less inverted.

VF has an Rs pattern.

G: Prone.

VR has more deeply inverted T.

VL has a smaller QS; T is flat.

VF shows reduction in R.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have rS patterns; P is diphasic and T upright.

V3 has an RS pattern; P and T are upright.

V4 and V5 have qRs patterns; P and T are upright.

V6 has a qR pattern; P and T are upright.

There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control but T is increased in VI to V3.

B: Standing.

VI and V2 have rS patterns with increase in S.

V3 has an RS pattern with increase in R and S.

V4 to V6 have qRs patterns.

T is increased in VI and V2 and decreased in V4 to V6.

There has been some clockwise rotation.

C: 45° head up.

The patterns are similar to those in B.

H: 45° head down.

VI and V2 have rS patterns with increase in r.

V3 has an Rs pattern with increase in R.

V4 and V5 have qRs patterns with increase in q and R.

V6 has a qR pattern with increase in R.

The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI and V2 have rS patterns.

V3 has an Rs pattern with increase in R.

V4 has a qRs pattern with increase in q.

V5 and V6 have qR patterns with increase in q and R.

T is increased in V2 to V6.

There has been some counter-clockwise rotation and forward rotation of the apex.

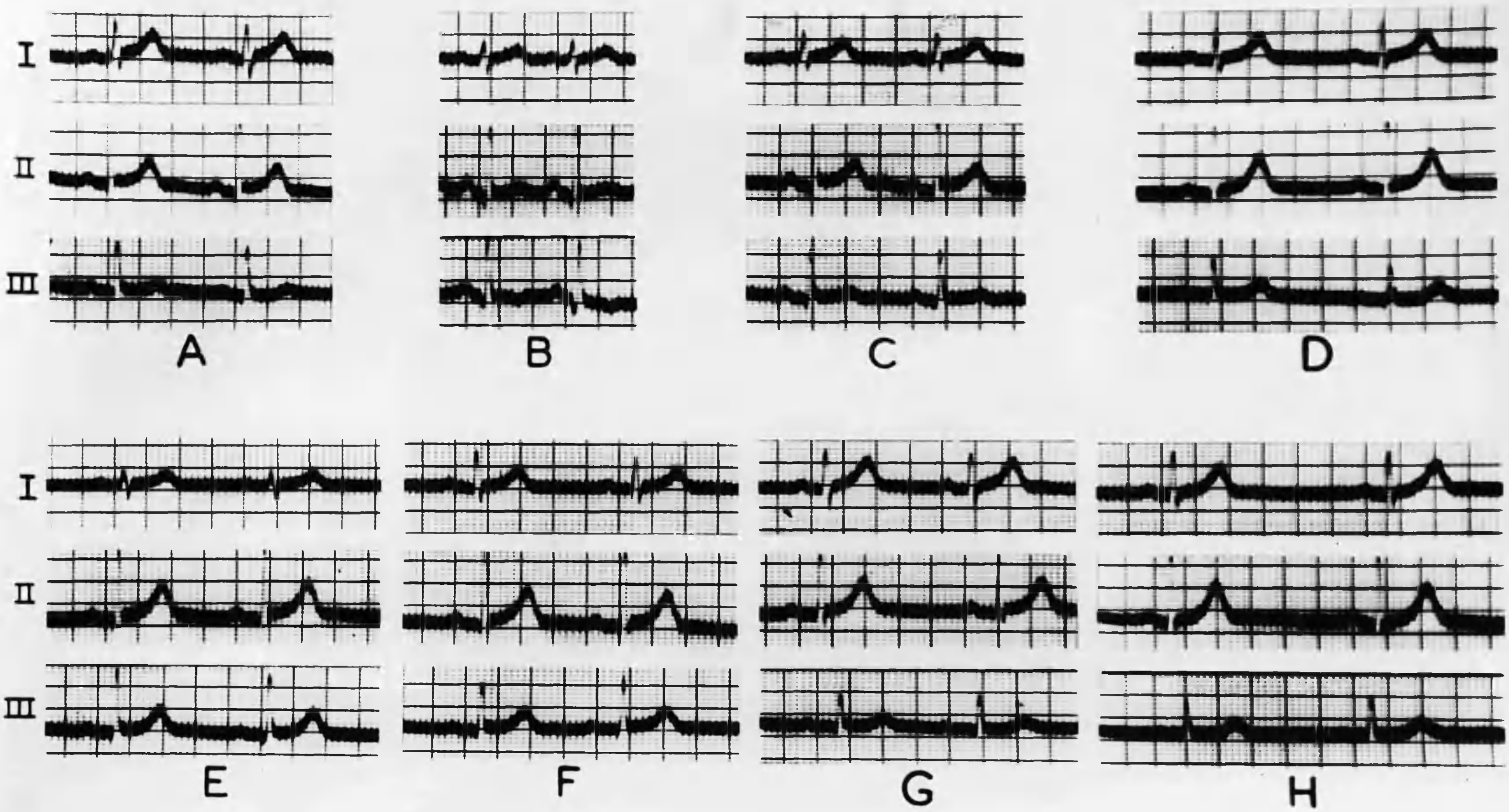
F: Right Lateral.

VI has an rS pattern with increase in r. V2 has an RS pattern. V3 has an Rs pattern. V4 and V5 have qRs patterns with increase in R. V6 has a qR pattern with increase in R. T is increased in VI to V3. Some displacement to the right has occurred.

G: Prone.

VI to V4 are similar to the control. V5 and V6 have qR patterns.

STANDARD LIMB LEADS



CASE NO. 7 PLATE I33a

NORMAL. E.M.

Age I9 years.

STANDARD LIMB LEADS.

D: Supine.

Leads I and II have upright P and T waves and qRs patterns.

Lead III has upright P and T waves and a qR pattern.

Vertical Rotation.

A: Sitting.

Lead I shows increase in R and s.

Lead II shows increase in R and reduction in s; T is reduced.

Lead III shows increase in q and R; T is reduced.

B: Standing.

Lead I has an RS pattern with reduction in R; T is reduced.

Lead II has a qR pattern; P is increased and T is reduced.

Lead III shows increase in q and R; P is increased and T is inverted.

C: 45° head up.

Lead I shows reduction in R and T.

Lead II has a qR pattern; P is increased and T is reduced.

Lead III shows increase in q and R; P is increased and T is reduced.

In A,B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in R and T.

Lead II shows increase in s and T.

There has been a slight shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

Lead I has an RS pattern with reduction in R; T is reduced.

Lead II shows increase in T.

Lead III shows increase in R and T.

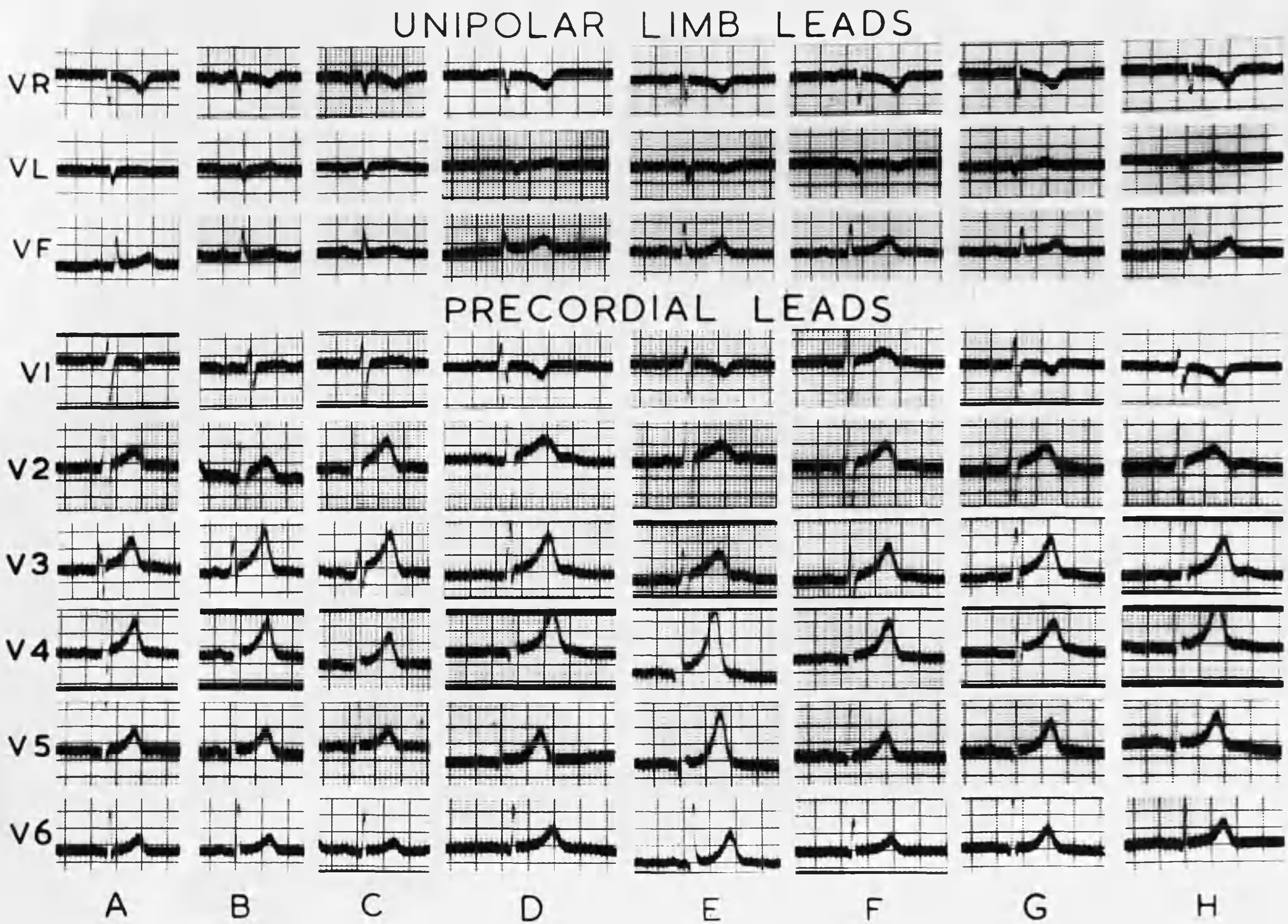
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows increase in R; T is reduced.
Lead II shows increase in R and s; T is increased.
Lead III shows increase in R and T.

G: Prone.

Lead I shows increase in R and T.
Lead II shows decrease in R and increase in s.
Lead III shows decrease in R and T.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
VI
V2
V3
V4
V5
V6
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F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VL has flat P and low upright T waves and an rs pattern. It faces the epicardial surface of the right ventricle.

VF has flat P and upright T waves and a qR pattern.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR has an rSr' pattern with increase in S.
VL has an rS pattern; T is reduced.
VF shows increase in R; P is upright.

B: Standing.

VR shows less inverted T.
VL has an rS pattern.
VF shows increase in R; P is upright and T is reduced.

C: 45° head up.

The changes are similar to those in B.

In A,B and C the heart has become more vertical.

H: 45° head down.

VR has an rSr' pattern.
VL is similar to the control.
VF shows increase in T.

Horizontal Rotation.

E: Left Lateral.

VR has an rSr' pattern; T is less inverted.
VL has an rS pattern; T is inverted.
VF shows increase in R and T; P is upright.

F: Right Lateral.

VR has an rSr' pattern.
VL has upright P and inverted T.
VF has a qRs pattern with increase in R; P is upright and T is increased.

G: Prone.

VR has an rSr' pattern with increase in S.
VL has an rs pattern.
VF shows increase in R.

PRECORDIAL LEADS.

D: Supine.

VI has a splintered rS pattern; P is upright and T is inverted.

V2 has an RS pattern; P and T are upright.

V3 has an Rs pattern; P and T are upright.

V4 to V6 have qRs patterns; P and T are upright.

There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns.

V3 has an RS pattern with reduction in R.

V4 to V6 have qRs patterns with reduction in R and increase in s.

T is slightly inverted in VI and reduced in all other leads.

B: Standing.

VI and V2 have rS patterns.

V3 has an RS pattern with reduction in S.

V4 to V6 have qRs patterns.

T is flat in VI and reduced in V2,V5 and V6.

C: 45° head up.

The patterns are similar to those in B.

In A,B and C the heart has become more vertical and there has been slight clockwise rotation.

H: 45° head down.

VI has a splintered rS pattern with reduction in S; T is more deeply inverted.

V2 to V6 are similar to the control but T is reduced in V2 and V3 and increased in V5 and V6.

The heart has become slightly more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns. V4 to V6 have qR patterns with increase in q and R.

T is reduced in V2 and V3 and increased in V4 to V6.

Displacement to the left has occurred with forward rotation of the apex.

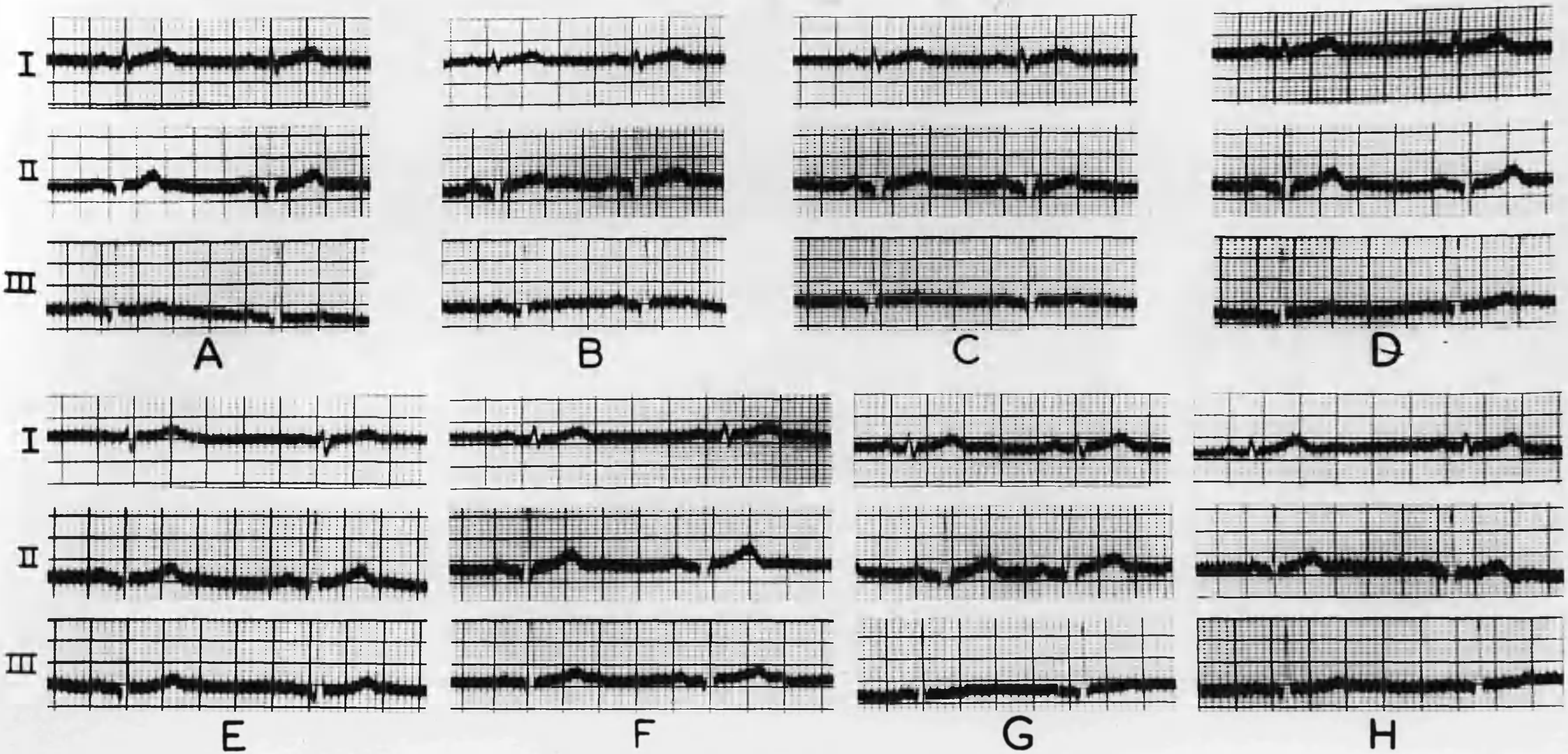
F: Right Lateral.

VI to V3 have RS patterns. V4 to V6 have qRs patterns with reduction in R. T is upright in VI and reduced in V4 to V6. Displacement to the right has occurred.

G: Prone.

The patterns are similar to the control but V5 and V6 show increase in R and T due probably to forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

J.R.

Age 2I years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has upright P and T waves and an RS pattern. Leads II and III have upright P and T waves and qRs patterns.
There is right axis deviation.

Vertical Rotation.
A: Sitting.
Lead I shows increase in R and S.
Lead II shows decrease in T.
Lead III shows increase in q and R; T is reduced.

B: Standing.
Lead I shows reduction in R and increase in S; T is reduced.
Lead II shows reduction in T; P is increased.
Lead III shows increase in q; T is flat; P is increased.

C: 45° head up.
The changes are similar to those in B.

In B and C there has been a shift of the QRS axis to the right.

H: 45° head down.
Lead I shows reduction in S.
Lead II shows reduction in R.
Lead III shows reduction in R.
There has been a shift of the QRS axis to the left.

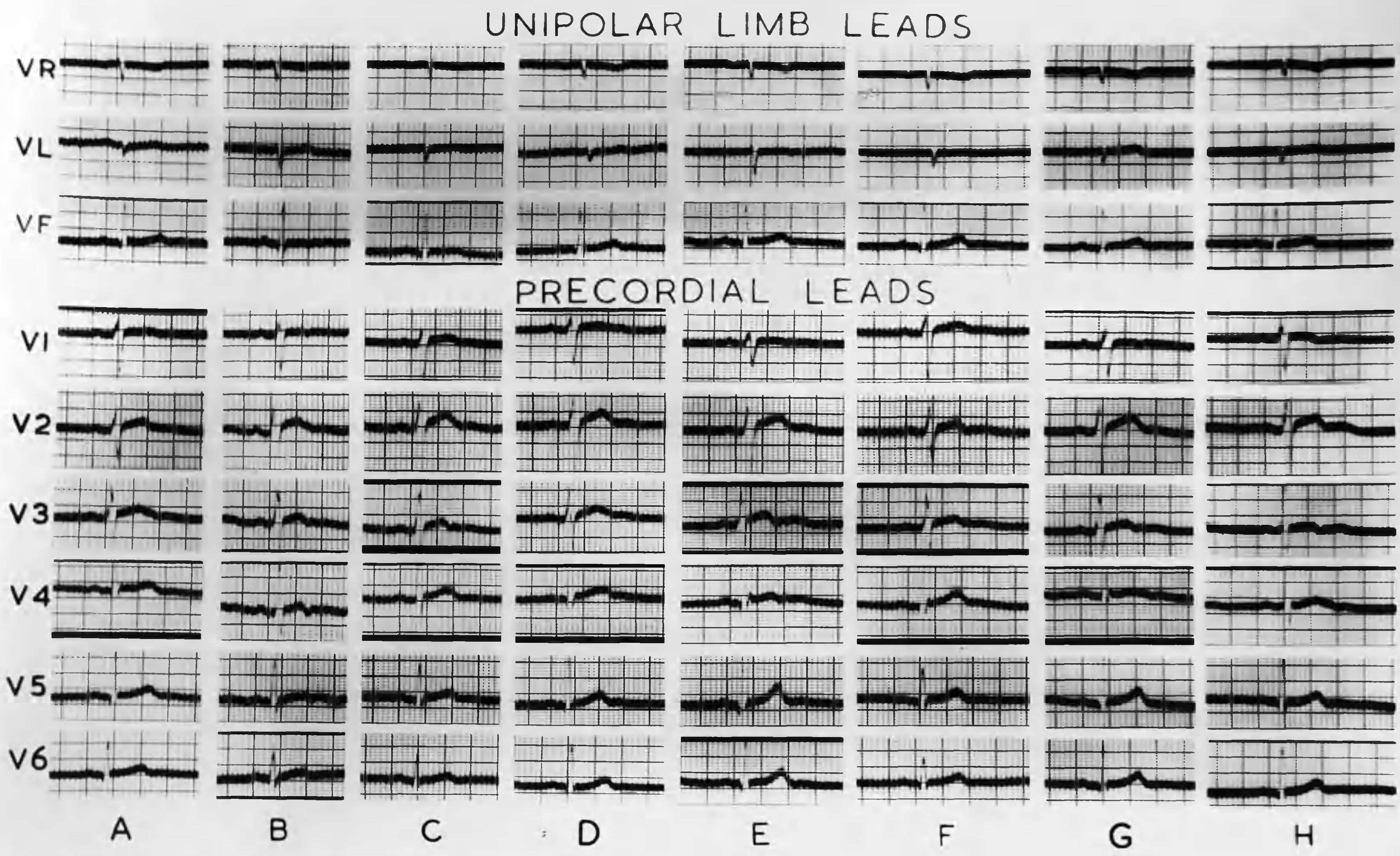
Horizontal Rotation.
E: Left Lateral.
Lead I has an rS pattern with increase in S; T is reduced.
Lead II shows reduction in s.
Lead III shows increase in q and R and reduction in s; T is increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead II shows increase in s; P and T are increased.
Lead III shows reduction in R and increase in s; P and T are increased.

G: Prone.
Lead I shows increase in R and S. Lead II shows increase in s; T is reduced.

G: Prone(contd.)

Lead III shows increase in s; T is reduced.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
VI
V2
V3
V4
V5
V6
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CASE NO. 4 (contd.)

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR has an rSr' pattern. It tends to face the epicardial surface of the right ventricle.

VL shows increase in S.

VF shows decrease in s.

B: Standing.

VR shows increase in Q and r; T is less inverted.

VL shows increase in S; T is increased.

VF shows increase in s; P is increased; T is slightly inverted.

C: 45° head up.

The changes are similar to those in B.

In B and C the heart has become more vertical.

H: 45° head down.

VR shows reduction in Q and increase in r.

VF shows reduction in R; T is reduced.

Horizontal Rotation.

E: Left Lateral.

VR has an rSr' pattern.

VL has an rS pattern; T is reduced.

VF shows reduction in R and s.

F: Right Lateral.

VR has an rSr' pattern.

VL shows reduction in r and increase in S; T is reduced.

VF shows increase in R; T is increased.

G: Prone.

VL shows increase in S; T is increased.

VF shows reduction in q.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have rS patterns; P and T are upright.
V3 has an RS pattern; P and T are upright.
V4 to V6 have qRs patterns; P and T are upright.
There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control.

B: Standing.

VI to V3 have rS patterns.
V4 has an Rs pattern.
V5 and V6 have qRs patterns with reduction in R and increase in s.
T is reduced in all leads.
There has been clockwise rotation.

C: 45° head up.

The patterns are similar to those in B but the reduction in T is less.

H: 45° head down.

VI and V2 have rS patterns.
V3 has an Rs pattern.
V4 to V6 have qRs patterns with increase in s.
The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI and V2 have rS patterns with reduction of r and S in VI.
V3 has an RS pattern.
V4 to V6 have qRs patterns with increase in q and R.
T is reduced in VI and increased in V5 and V6.
There has been slight displacement to the left with forward rotation of the apex.

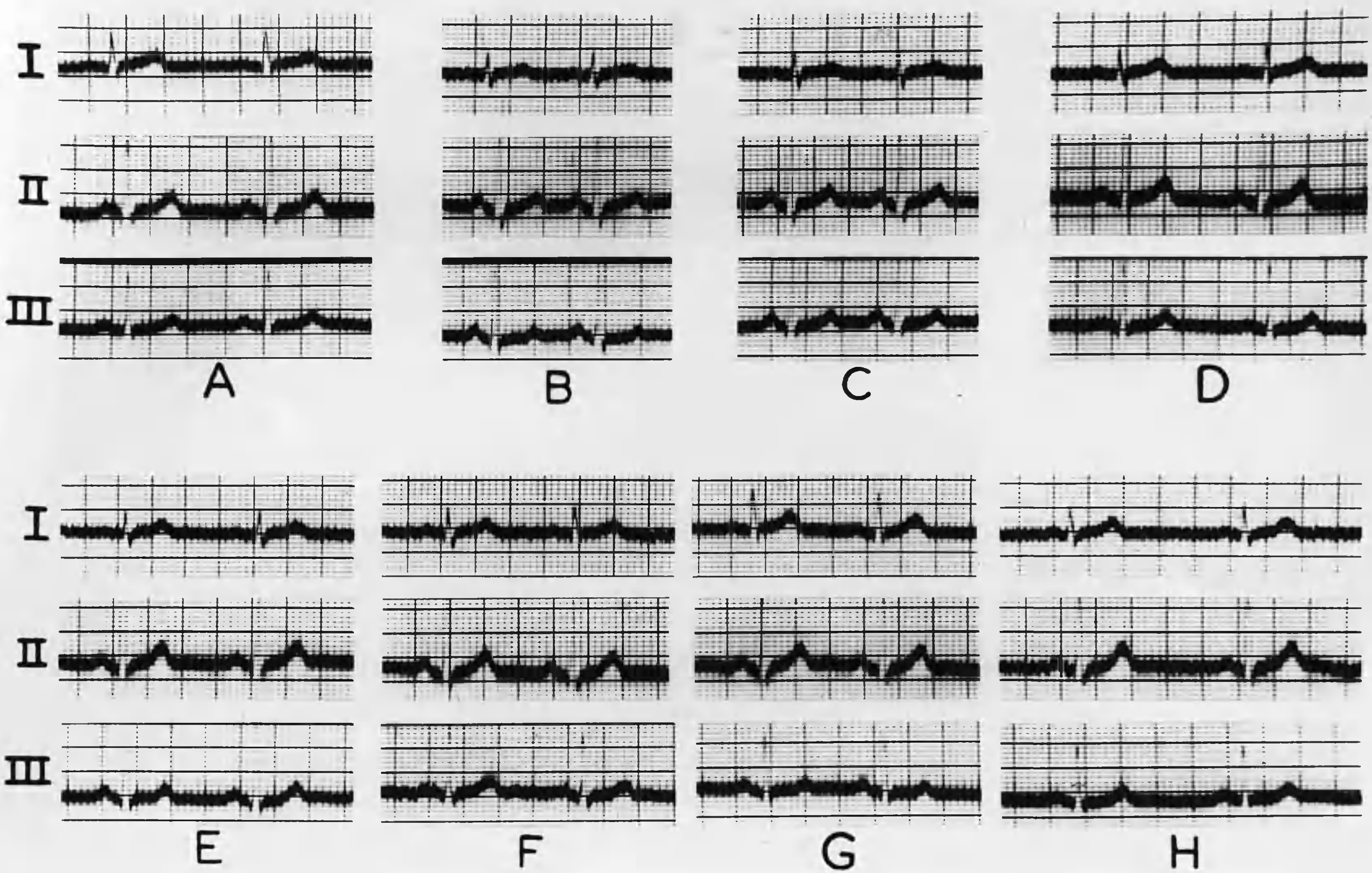
F: Right Lateral.

VI has an rS pattern with increase in r and S.
V2 and V3 have RS patterns.
V4 to V6 have qRs patterns with decrease of R in V5 and V6.
Displacement to the right has occurred with backward rotation of the apex.

G: Prone.

VI to V3 are similar to the control.
V4 to V6 are similar to E.
There has been some forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

J.I.

Age 36 years.

STANDARD LIMB LEADS.

D: Supine.
All leads have upright P and T waves and qRs patterns.

Vertical Rotation.
A: Sitting.
Lead I shows increase in R; q and s are also increased.
Lead II shows increase in P; T is reduced.
Lead III shows increase in P; T is reduced.

B: Standing.
Lead I has an Rs pattern with reduction in R and increase in s; T is reduced.
Lead II shows increase in R and s; P is increased; T is reduced.
Lead III shows increase in R and s; P is increased; T is reduced.

C: 45° head up.
The changes are similar to those in B.

In B and C there has been a shift of the QRS axis to the right.

H: 45° head down.
Lead I shows increase in R; T is increased.
Lead II shows increase in s; T is increased.
Lead III shows reduction in R.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.
E: Left Lateral.
Lead I has an Rs pattern with reduction in R and increase in s.
Lead II shows increase in q and R; P is increased; T is increased.
Lead III shows increase in q,R and s; P is increased; T is increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead II shows increase in s.
Lead III shows increase in s.

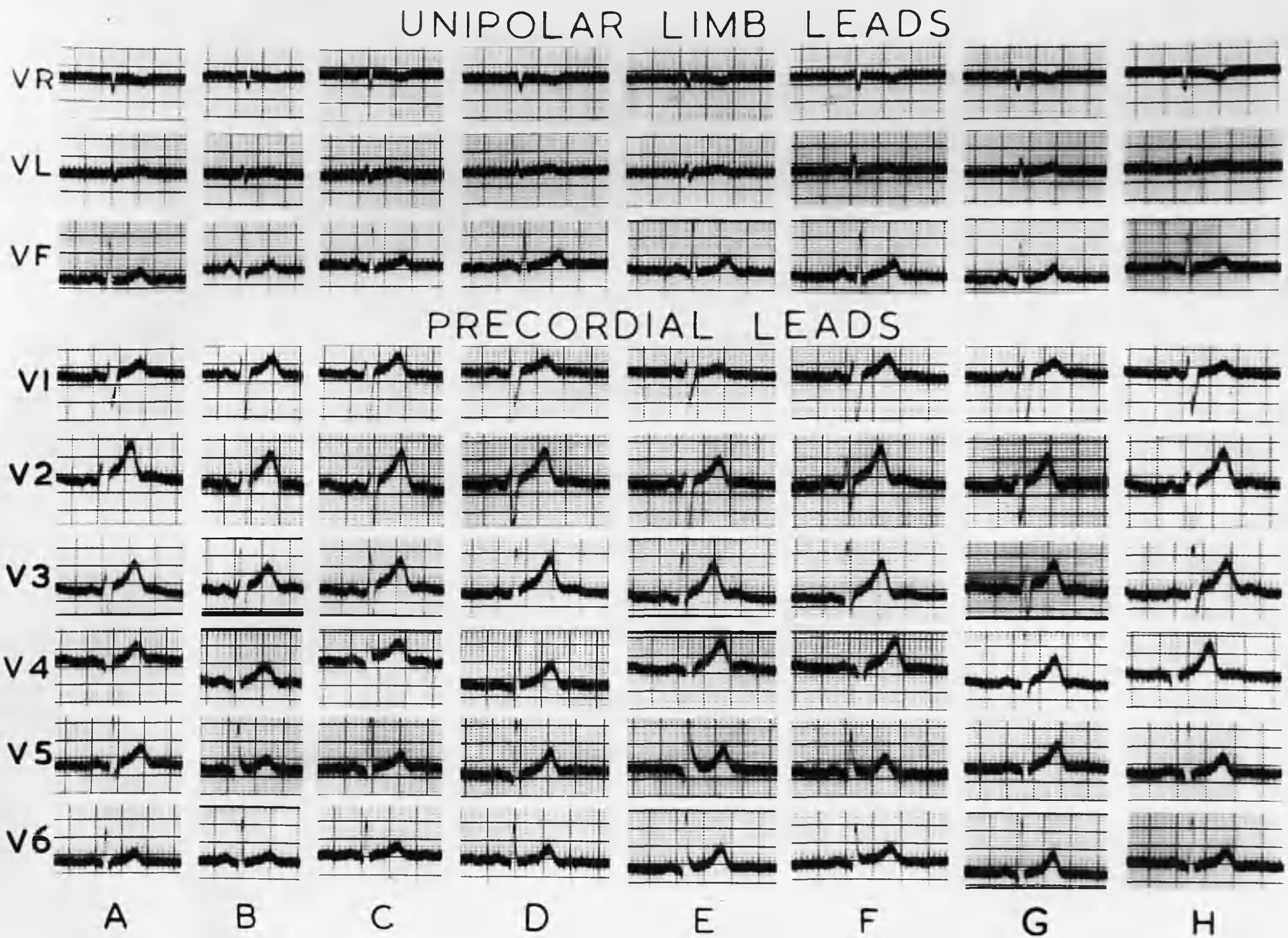
G: Prone.

Lead I shows increase in R and reduction in s; T is increased.

Lead II shows increase in s.

Lead III shows reduction in R and increase in s; T is reduced.

There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
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CASE NO. 5 (contd.) PLATE I35b

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

VL has flat P and upright T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VL has an RS pattern.

VF has a qR pattern with increase in R.

B: Standing.

VR shows reduction in S; T is less inverted.

VL has an RS pattern with reduction in R; T is reduced.

VF shows increase in R and s; P is increased; T is reduced.

The heart has become more vertical.

C: 45° head up.

The patterns are similar to those in B.

H: 45° head down.

VR shows increase in S and r'; T is more inverted.

VL shows decrease in s.

VF shows decrease in R and increase in s.

Horizontal Rotation.

E: Left Lateral.

VR shows decrease in S.

VL has an RS pattern with decrease in R.

VF shows increase in q and R; T is increased.

F: Right Lateral.

VR shows increase in S; T is more inverted.

VL shows increase in R and s.

VF shows increase in R and s; P is increased; T is increased.

G: Prone.

VR shows increase in S; T is more inverted.

VL shows increase in R; T is increased.

VF has a qR pattern with reduction in R.

PRECORDIAL LEADS.

D: Supine.
VI and V2 have rS patterns; P and T are upright.
V3 has an Rs pattern; P and T are upright.
V4 to V6 have qRs patterns; P and T are upright.
There is moderate counter-clockwise rotation.

Vertical Rotation.
A: Sitting.
VI to V3 have rS patterns.
V4 to V6 have qRs patterns with reduction in R and increase in s.
T is reduced in V4 to V6.

B: Standing.
VI to V3 have rS patterns.
V4 to V6 have qRs patterns with reduction in R.
T is increased in VI and reduced in all other leads.

C: 45° head up.
The patterns are similar to those in B.

In A, B and C there has been slight clockwise rotation.

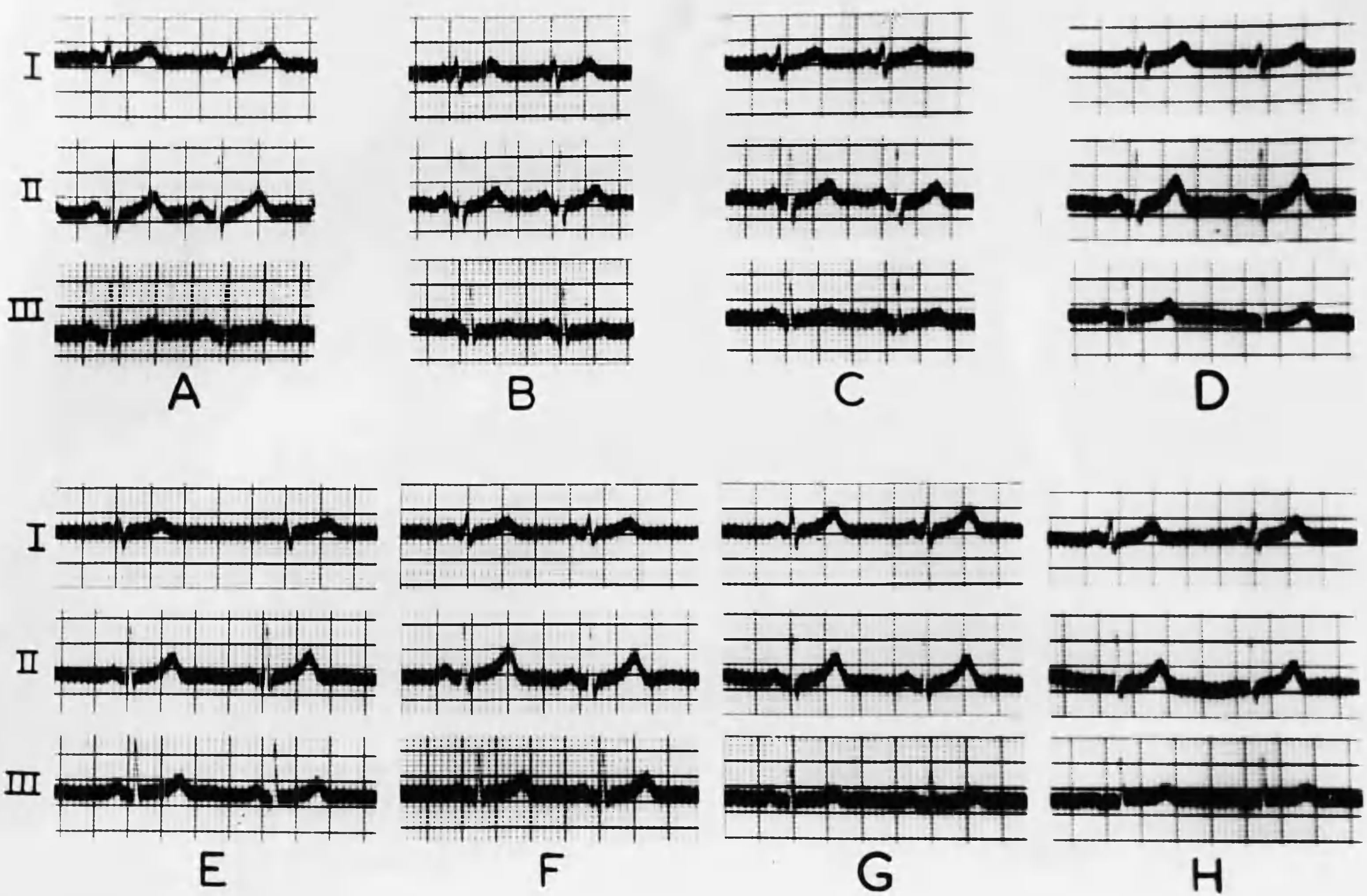
H: 45° head down.
The patterns are similar to the control but there is increase in s in V3 to V6.
The heart has probably become more horizontal.

Horizontal Rotation.
E: Left Lateral.
VI and V2 have rS patterns with reduction of r and S in VI and of r in V2.
V3 has an Rs pattern with increase in s.
V4 has a qRs pattern.
V5 and V6 have qR patterns with increase in q and R.
T is reduced in VI and V2 and increased in V4 to V6.
Some displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.
VI has an rS pattern with increase in r and S.
V2 has an RS pattern.
V3 and V4 have qRs patterns.
V5 and V6 have qR patterns with reduction in R.
T is increased in VI and V2 and reduced in V5 and V6.
Displacement to the right has occurred.

G: Prone.
VI to V3 have rS patterns. V4 to V6 have qRs patterns with increase in q and R due to forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

W.R.

Age 26 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an Rs pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has diphasic P and upright T waves and a qRs pattern.
There is a tendency to right axis deviation.

Vertical Rotation.

A: Sitting.

Lead II shows increase in P,R and s; T is reduced.
Lead III shows increase in P,R and s; T is reduced.

B: Standing.

Lead I has an RS pattern with reduction in R; T is reduced.
Lead II shows increase in P,q and s; T is reduced.
Lead III shows increase in P,q,R and s; T is reduced.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A,B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in R; T is increased.
Lead II shows decrease in R; P is flat and T is reduced.
Lead III shows inversion of P; T is reduced.

Horizontal Rotation.

E: Left Lateral.

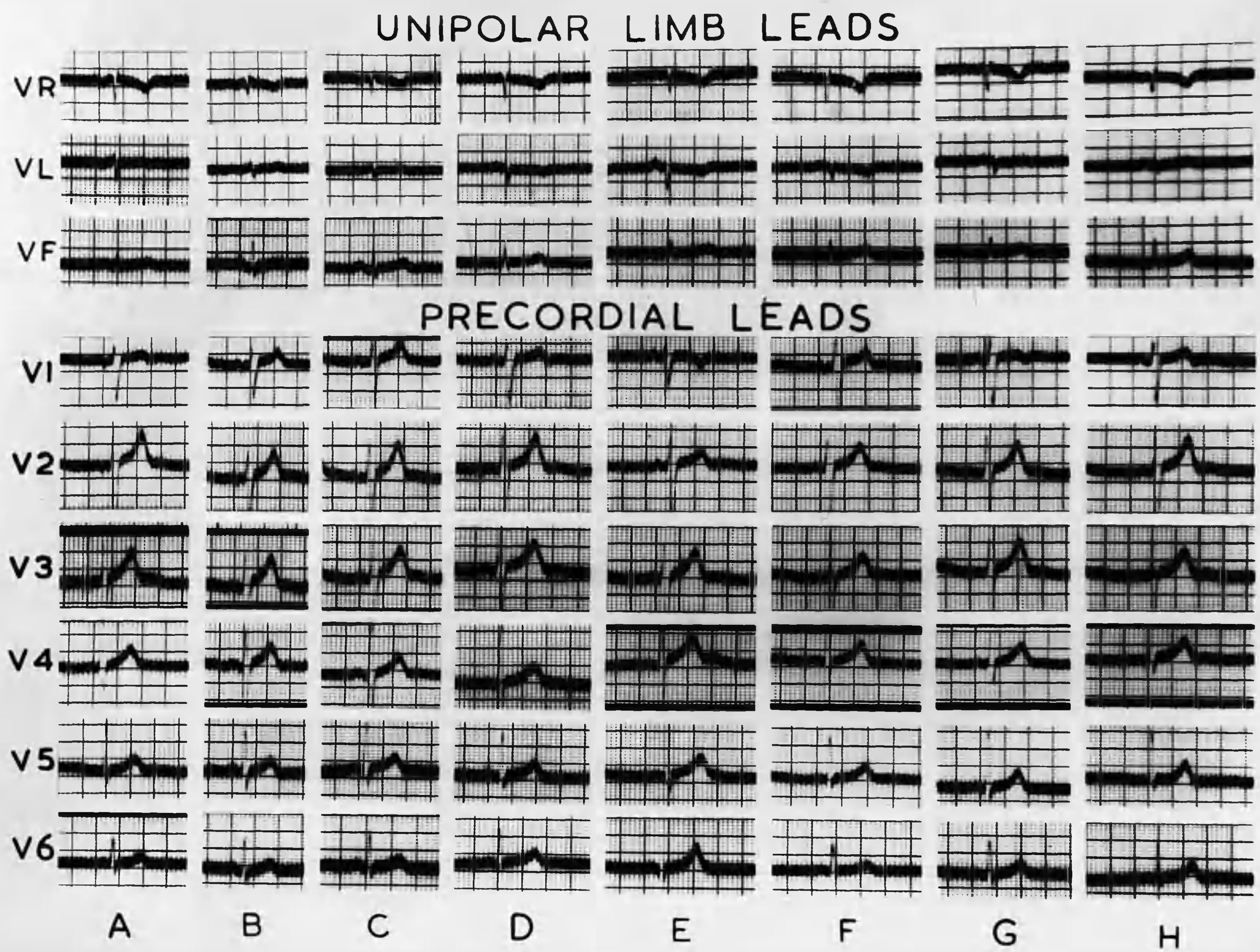
Lead I has an RS pattern with reduction in R; T is reduced.
Lead II shows reduction in R and s; T is reduced.
Lead III shows increase in R.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows increase in R and reduction in s; T is reduced.
Lead II shows reduction in R; P is increased.
Lead III shows increase in P,s and T.
There has been a shift of the QRS axis to the left.

G: Prone.

Lead I shows increase in R and s; T is increased.
Lead II shows reduction in R.
Lead III shows reduction in R and T.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
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PRECORDIAL LEADS
V1
V2
V3
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CASE NO. 6 (contd.)

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and inverted T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has flat P and upright T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VL shows increase in S; P is slightly inverted and T is flat.

VF shows upright P; T is reduced.

B: Standing.

VR shows reduction in Q; T is less inverted.

VL has an rs pattern with increase in r; P is slightly inverted and T is upright.

VF shows increase in q,R and s; P is upright and T is reduced.

C: 45° head up.

The changes are similar to those in B but are less marked.

H: 45° head down.

VL has an rs pattern; P and T are upright.

VF shows increase in R and T.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in Q and r.

VL has an rSr' pattern with increase in S; P is increased and T is more inverted.

VF shows reduction in R and s.

F: Right Lateral.

VR shows increase in Q; T is more inverted.

VL has a Qr pattern; T is more inverted.

VF shows reduction in R.

G: Prone.

VR shows increase in Q; T is more inverted.

VL shows reduction in S; T is flat.

VF shows reduction in R.

PRECORDIAL LEADS.

D: Supine.

VI has an rS pattern; P and T are upright.
V2 and V3 have RS patterns; P and T are upright.
V4 has an Rs pattern; P and T are upright.
V5 and V6 have qRs patterns; P and T are upright.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns; P is diphasic.
V3 has an RS pattern.
V4 and V5 have Rs patterns.
V6 has a qRs pattern with reduction in R.
T is reduced in VI,V5 and V6.
There has been further clockwise rotation.

B: Standing.

VI to V3 have rS patterns; P is diphasic.
V4 has an RS pattern.
V5 has an Rs pattern with increase in s.
V6 has a qRs pattern with reduction in R and increase in s.
T is reduced in V5 and V6.
There has been further clockwise rotation.

C: 45° head up.

The patterns are similar to the control.

H: 45° head down.

The patterns are similar to the control but R and T are increased in V5 and V6.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns with increase in q,R and s.
T is inverted in VI, reduced in V2 and increased in V4 to V6.
Displacement to the left has occurred with forward rotation of the apex.

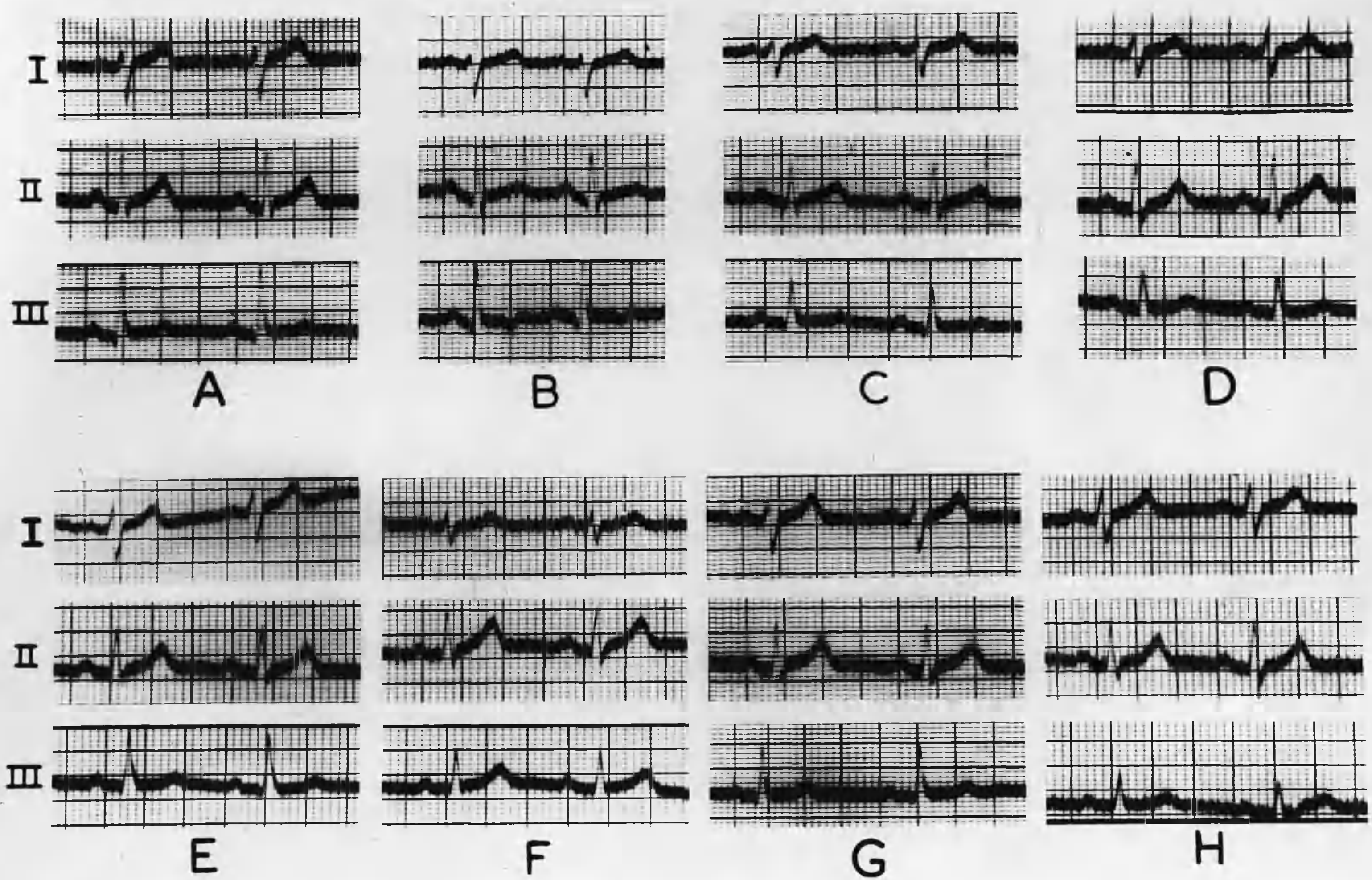
F: Right Lateral.

The patterns are similar to the control but r and T are increased in VI; R,s and T are reduced in V5 and V6.
Displacement to the right has occurred.

G: Prone.

The patterns are similar to the control.

STANDARD LIMB LEADS



NORMAL.

I.M.

Age 20 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has an RS pattern; P and T are upright.
Lead II has a qRs pattern; P and T are upright.
Lead III has a qR pattern; P and T are upright.
There is right axis deviation.

Vertical Rotation.

A: Sitting.
Lead I has an rS pattern with increase in S; T is increased.
Lead II shows increase in R and reduction in s.
Lead III shows increase in q and R; T is reduced.

B: Standing.
Lead I has an rS pattern, with increase in S.
Lead II shows increase in q; P is increased and T is reduced.
Lead III shows increase in q and R; P is increased; T is inverted.

C: 45° head up.
Lead I has an rS pattern with increase in S.
Lead II shows reduction in R and s; T is reduced.
Lead III shows increase in q and R; T is reduced.

In A, B and C there has been a shift of the QRS axis to the right.

H: 45° head down.
Lead I has an RS pattern with increase in R and S; T is increased.
Lead II shows increase in T.
Lead III has a reduced R pattern; T is increased.

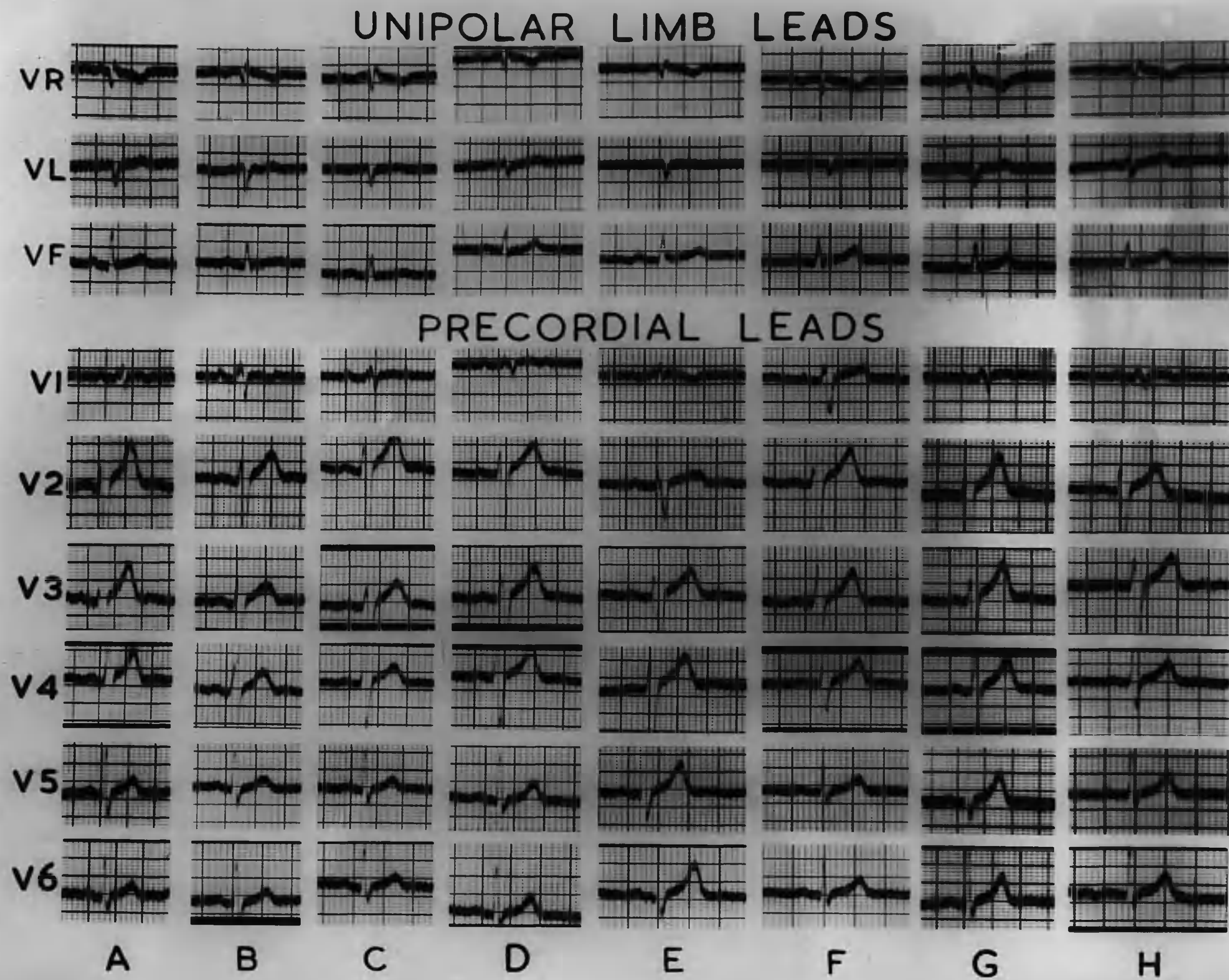
Horizontal Rotation.

E: Left Lateral.
Lead I shows increase in S.
Lead II shows reduction in R and s.
Lead III shows increase in R.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead I shows reduction in R and S.
Lead II shows reduction in R and s; T is increased.
Lead III has a qRs pattern with reduction in q and R; T is increased.

G: Prone.

Lead I shows increase in S; T is increased.
Lead II shows reduction in R and s; T is increased.
Lead III shows increase in R.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
VI
V2
V3
V4
V5
V6
A
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G
H

CASE NO. 7 (contd.)

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a QR pattern. It faces the back of the heart.

VL has upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows increase in Q; T is more inverted.
VL shows increase in S.
VF shows increase in R.

B: Standing.

VR shows less inverted T.
VL shows increase in S.
VF shows increase in q and R; T is reduced.

C: 45° head up.

The changes are similar to those in B.

In A,B and C the heart has become more vertical.

H: 45° head down.

VL shows increase in r; T is increased.
VF shows reduction in s.
The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in Q and R; T is less inverted.
VL shows increase in S; T is flat.
VF has a qR pattern.
There has probably been some forward rotation of the apex.

F: Right Lateral.

VR has a Qr pattern.
VL shows reduction in S; T is flat.
VF shows increase in R and T.

G: Prone.

VR shows more deeply inverted T.
VL shows increase in S and T.
VF shows increase in R and reduction in s; T is increased.
There has probably been some forward rotation of the apex.

PRECORDIAL LEADS.

D: Supine.

VI has an rsr'S' pattern; P is upright and T diphasic.

V2 and V3 have rS patterns; P and T are upright.

V4 has an RS pattern; P and T are upright.

V5 and V6 have qRs patterns; P and T are upright.

There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI has an rsR'S' pattern; T is inverted.

V2 to V4 have rS patterns.

V5 and V6 have qRs patterns with increase in s; T is reduced.

There has been slight clockwise rotation.

B: Standing.

VI to V4 have rS patterns.

V5 and V6 have qRs patterns with increase in s.

T is reduced in V3 to V6.

There has been further clockwise rotation and the heart has become more vertical.

C: 45° head up.

VI has an rsR'S' pattern.

Otherwise the patterns are similar to the control with reduction of T in V3 to V6.

H: 45° head down.

VI to V3 are similar to the control.

V4 has an Rs pattern.

V5 and V6 have qRs patterns with reduction in s.

T is increased in V5 and V6.

The heart has become more horizontal and there has been slight counter-clockwise rotation.

Horizontal Rotation.

E: Left Lateral.

VI has an rsR's' pattern. V2 has a splintered rS pattern. V3 and V4 have rS patterns. V5 and V6 have qRs patterns with increase in q, R and s.

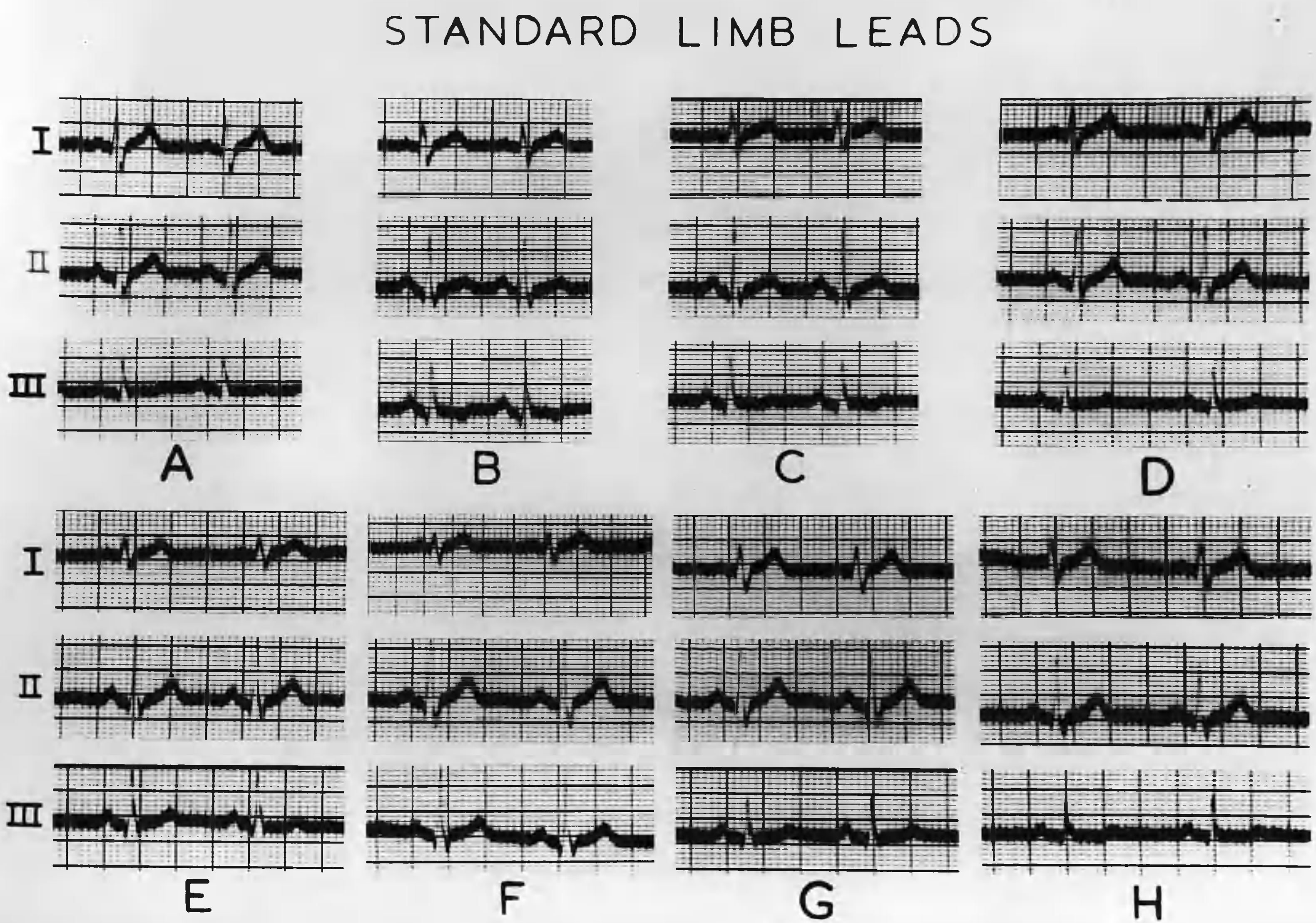
T is inverted in VI, reduced in V2 and increased in V5 and V6. Displacement to the left has occurred along with forward rotation of the apex.

F: Right Lateral.

VI to V3 have rS patterns. V4 has an Rs pattern. V5 and V6 have qRs patterns with reduction in R and s. T is upright in VI and reduced in V4 to V6. Displacement to the right has occurred with backward rotation of the apex.

G: Prone.

The patterns are similar to the control but R and T are increased in V5 and V6, due to forward rotation of apex.


STANDARD LIMB LEADS
I
II
III
A
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I
II
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H

NORMAL. J.K.

Age 23 years.

STANDARD LIMB LEADS.

D: Supine.

Leads I and II have upright P and T waves and qRs patterns.

Lead III has upright P and T waves and a qR pattern.

There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I has a qRS pattern with increase in R; T is larger.

Lead II shows increase in R and s.

Lead III shows reduction in R; T is reduced.

B: Standing.

Lead I has a qRS pattern with reduction in R; T is reduced.

Lead II shows increase in q; P is increased and T is reduced.

Lead III shows increase in q and R; P is increased and T is inverted.

C: 45° head up.

The changes are similar to those in B but are less marked.

In B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in T.

Lead III shows reduction in T.

Horizontal Rotation.

E: Left Lateral.

Lead I has a qRS pattern with reduction in R; T is reduced.

Lead II shows increase in R; P is increased.

Lead III shows a qRs pattern with increase in R; P and T are increased.

There has been a shift of the QRS axis to the right.

F: Right Lateral.

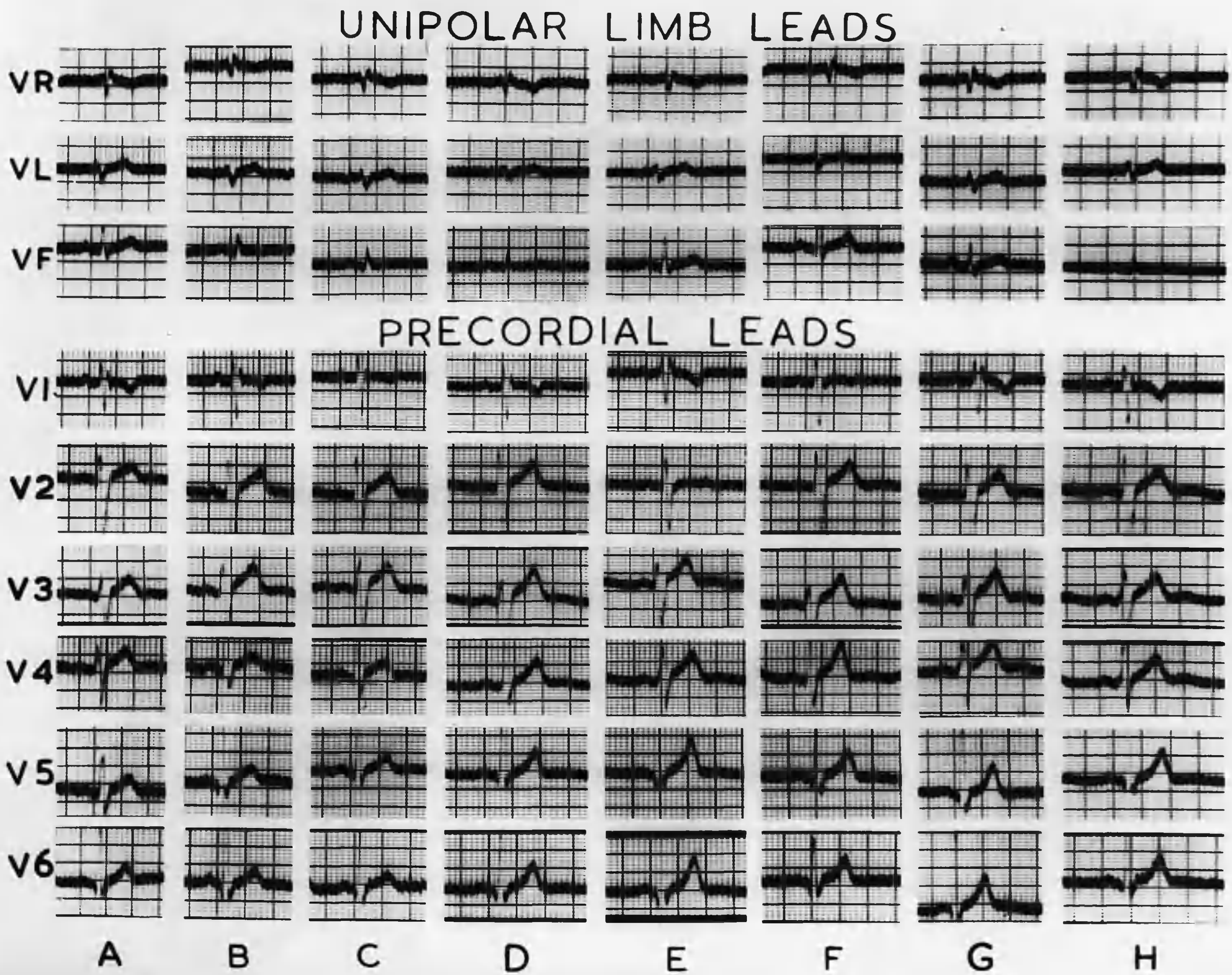
Lead I has a qRS pattern with reduction in R; T is reduced.

Lead II shows increase in q,R and s; P and T are increased.

Lead III has a qRs pattern with increase in q and R; P and T are increased.

G: Prone.

Leads I and II show slight increase in T.
Lead III has a qRs pattern.
P is increased in leads II and III.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
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V1
V2
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V4
V5
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

VL has diphasic P and upright T waves and a splintered rs pattern. It faces the epicardial surface of the right ventricle.

VF has low upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows increase in S and r'; T is less inverted.

VL has an rS pattern; T is increased.

VF has a qRs pattern with increase in R; P and T are increased.

B: Standing.

VR shows less inverted T.

VL has an rS pattern; P is inverted; T is increased.

VF shows increase in R; T is slightly inverted.

C: 45° head up.

The changes are similar to those in B.

In A,B and C the heart has become more vertical.

H: 45° head down.

VL has an RS pattern; T is increased.

VF shows reduction in R; T is reduced.

The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in S; T is less inverted.

VL has a splintered rS pattern.

VF has a qRs pattern with increase in R; T is increased.

F: Right Lateral.

VL has a splintered rS pattern; T is reduced.

VF has a qRs pattern with increase in R; T is increased.

G: Prone.

VL has an RS pattern; T is increased.

VF has a qRs pattern with increase in R; P and T are increased.

The heart has become less vertical.

PRECORDIAL LEADS

D: Supine.

VI has an rSr's' pattern; P is diphasic and T inverted.

V2 and V3 have rS patterns; P and T are upright.

V4 has an Rs pattern; P and T are upright.

V5 and V6 have qRs patterns; P and T are upright.

There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI has an rSr's' pattern.
V2 and V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qRs pattern.
T is reduced in V2 to V6.
There has been clockwise rotation.

B: Standing.

The patterns are similar to the control but T is reduced in V2 to V6.

C: 45° head up.

The patterns are similar to those in B.

In B and C the heart has probably become more vertical.

H: 45° head down.

The patterns are similar to the control but T is more inverted in VI and is increased in V5 and V6.

The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI has an rSr' pattern. V2 and V3 have rS patterns. V4 has an RS pattern with reduction in R. V5 and V6 have qRs patterns with increase in q and R.

T is more inverted in VI, reduced in V2 and V3 and increased in V4 to V6.

Displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

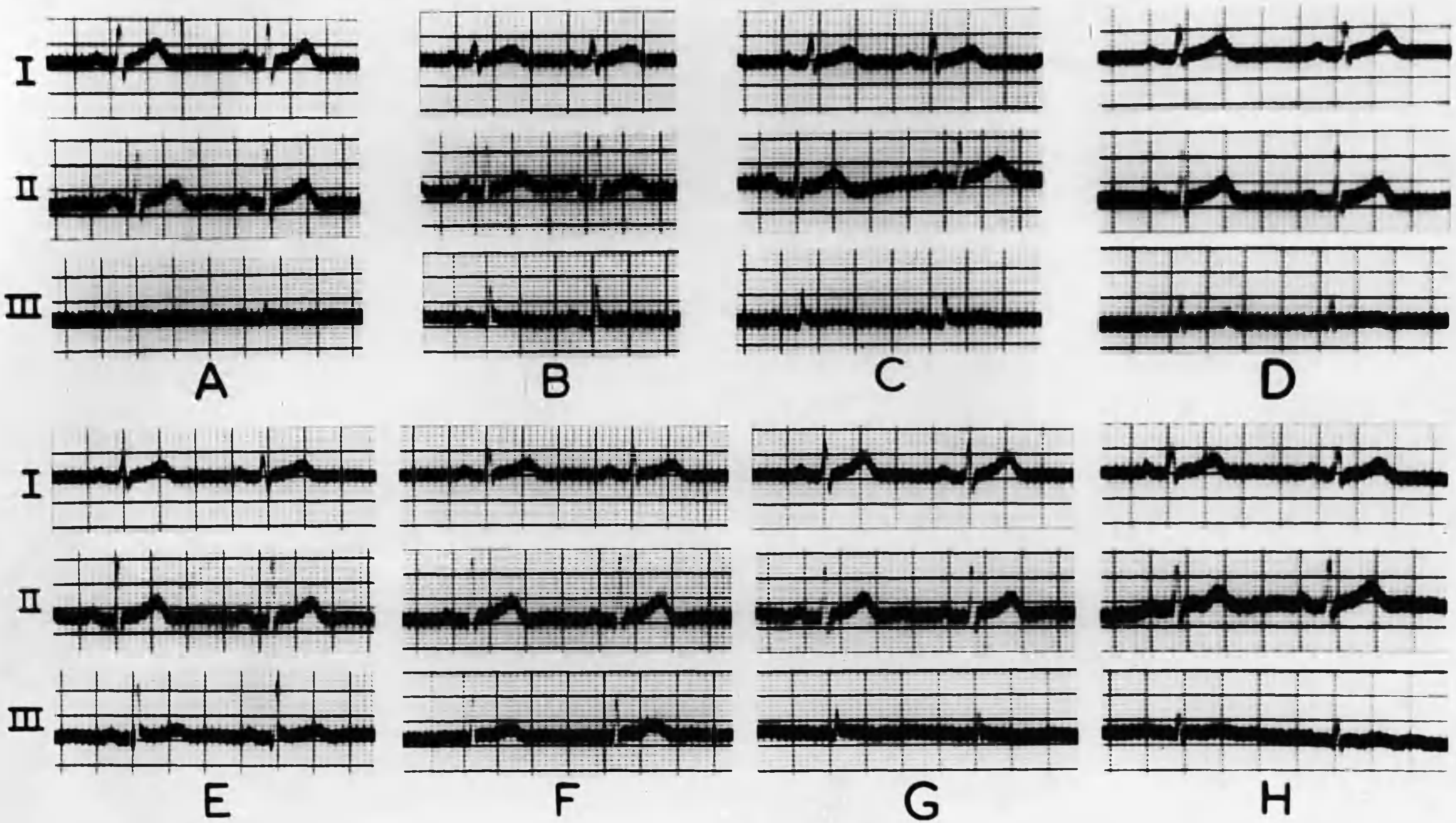
VI has a splintered rS pattern. V2 and V3 have rS patterns. V4 has an Rs pattern. V5 and V6 have qRs patterns with reduction in R and increase in s.

T is flat in VI. Displacement to the right has occurred.

G: Prone.

The patterns are similar to those in E but are less marked.

STANDARD LIMB LEADS



NORMAL.

W.P.

Age 2I years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has upright P and T waves and an Rs pattern.
Leads II and III have upright P and T waves and qRs patterns.

Vertical Rotation.
A: Sitting.
Lead I shows increase in R and s; T is increased.
Lead II has an Rs pattern with increase in R.
Lead III has an Rsr' pattern with reduction in R; T is diphasic.

B: Standing.
Lead I has an RS pattern with reduction in R; T is reduced.
Lead II shows increase in P and reduction in T.
Lead III has a qR pattern with increase in R; P is increased; T is flat.

C: 45° head up.
The changes are similar to those in B but are less marked.

In B and C there has been a shift of the QRS axis to the right.

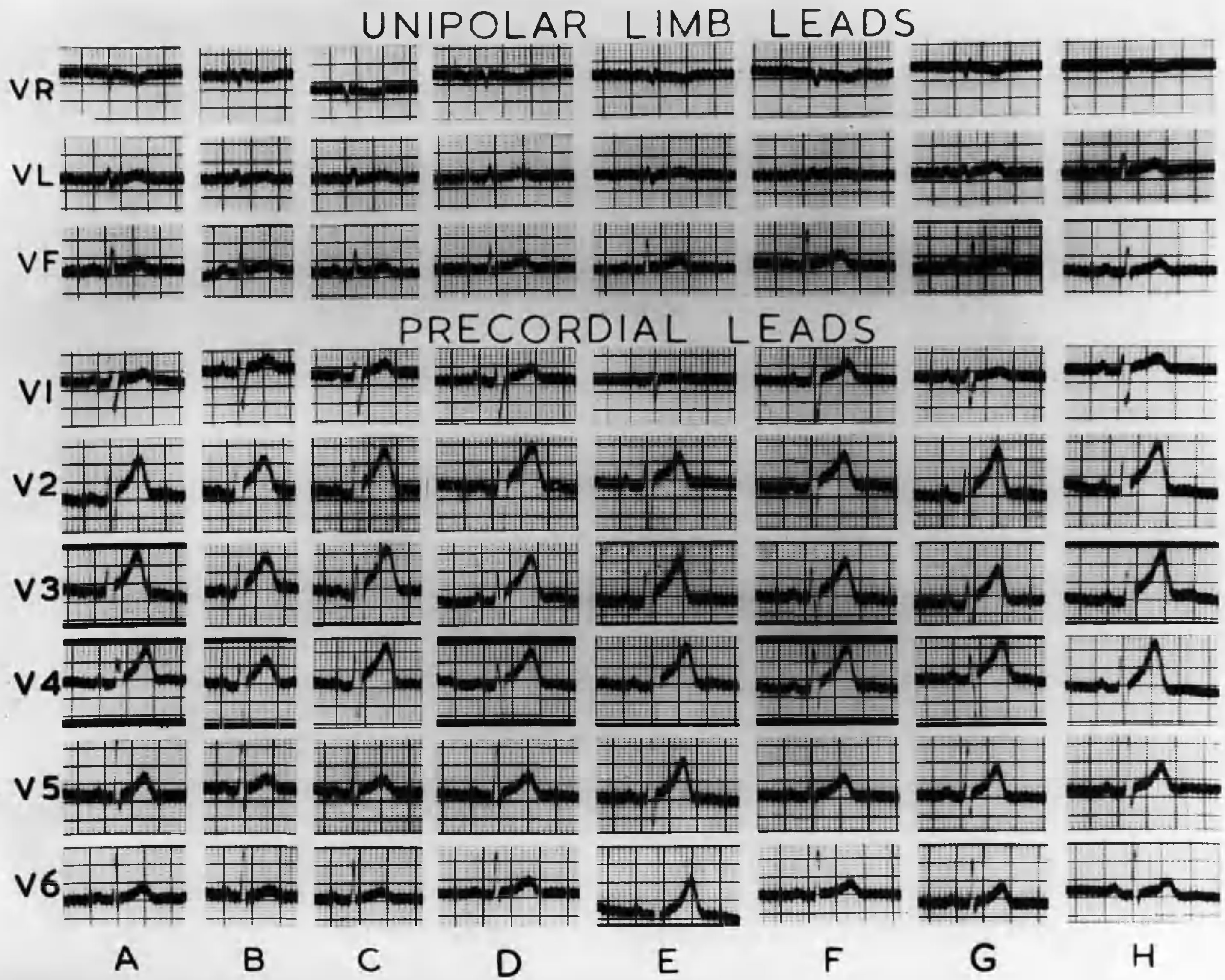
H: 45° head down.
Lead II shows reduction in R.
Lead III shows reduction in R and increase in s.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.
E: Left Lateral.
Lead I shows reduction in R and increase in s; P and T are reduced.
Lead II shows increase in R and reduction in s; T is reduced.
Lead III has a qR pattern with increase in q and R; P and T are increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead I shows reduction in R and s; T is reduced.
Lead II shows increase in R and reduction in s; T is reduced.
Lead III shows increase in R; T is increased.

G: Prone.

Lead I shows increase in R and s; T is increased.
Lead III shows reduction in R; T is flat.
There has been a shift of the QRS axis to the left.



UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
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UNIPOLAR LIMB LEADS.

D: Supine.
VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.
VL has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.
VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.
The heart is vertical.

Vertical Rotation.
A: Sitting.
VR has a QS pattern.
VL has an RS pattern.
VF has a qR pattern.

B: Standing.
VR shows reduction in Q; T is less inverted.
VL has an rs pattern; T is reduced.
VF has a qR pattern with increase in R; P is increased and T is reduced.

C: 45° head up.
The changes are similar to those in B.

In B and C the heart has become more vertical.

H: 45° head down.
VR shows reduction in Q; P and T are less inverted.
VL has an Rs pattern with increase in R; T is increased.
VF has a qRs pattern with increase in R; P and T are increased.
The heart has become less vertical.

Horizontal Rotation.
E: Left Lateral.
VR shows reduction in Q; T is less inverted.
VL has an RS pattern with reduction in R; T is reduced.
VF shows increase in R and reduction in s.

F: Right Lateral.
VL has an r pattern; T is reduced.
VF shows increase in R and T.

G: Prone.
VR shows reduction in Q and increase in r.
VL has an RS pattern; T is increased.
VF shows reduction in T.

PRECORDIAL LEADS.

D: Supine.

VI to V4 have rS patterns; P and T are upright.
V5 has an Rs pattern; P and T are upright.
V6 has a qRs pattern; P and T are upright.

There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control.

B: Standing.

The patterns are similar to the control but T is reduced in V2 to V6.

C: 45° head up.

The patterns are similar to the control but T is reduced in V5 and V6.

In B and C the heart has become slightly more vertical.

H: 45° head down.

The patterns are similar to the control but r is increased in V4 and R is increased in V5 and V6; T is increased in V2 to V6.

The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

The patterns are similar to the control but r and S are reduced in VI; R is increased in V5; q and R are increased in V6; T is flat in VI, reduced in V2 and increased in V4 to V6.

Displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

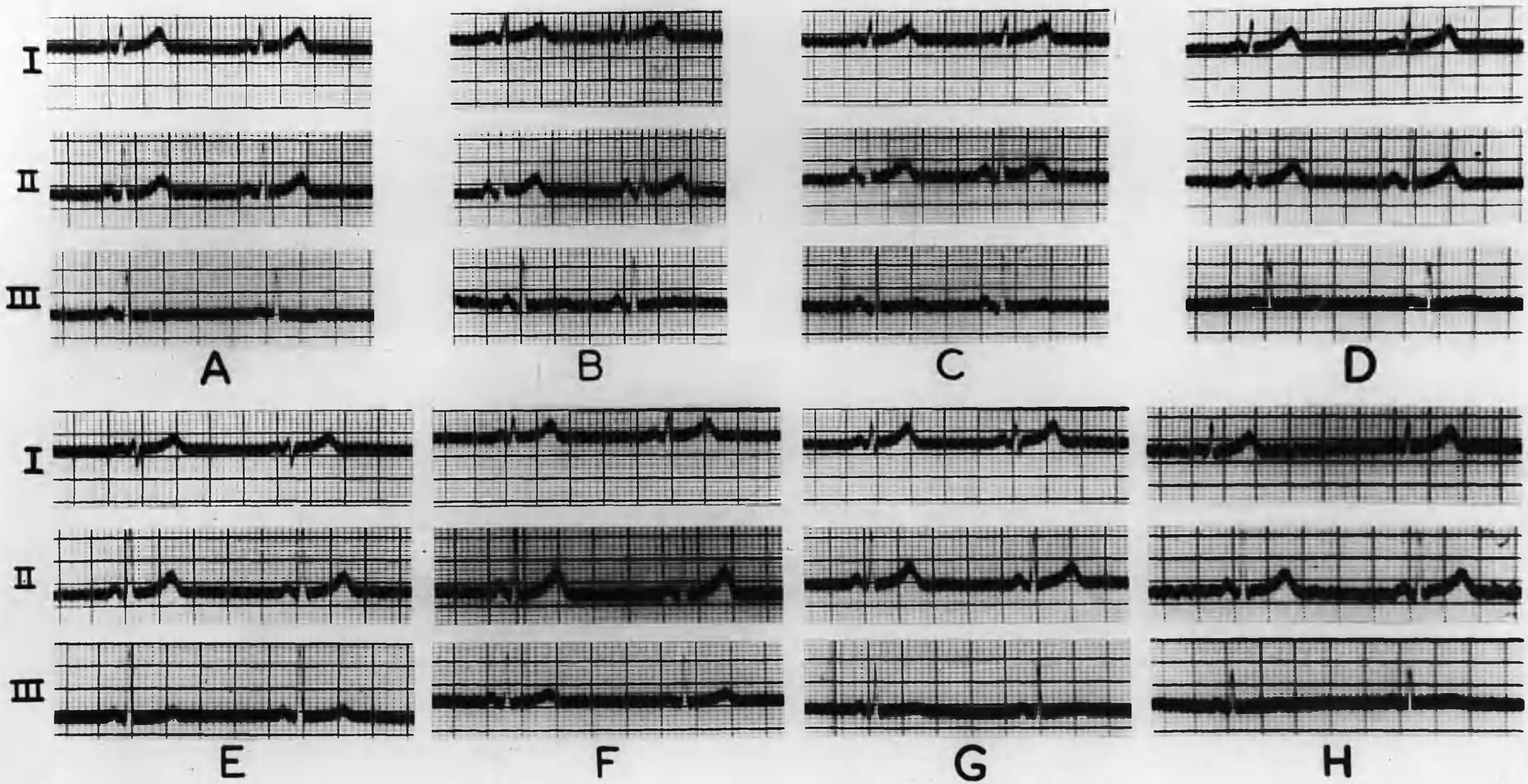
VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern with reduction in R and s.
V6 has a qRs pattern with reduction in s.
T is increased in VI and reduced in V2.
Some displacement to the right has occurred.

G: Prone.

The patterns are similar to the control but r, S and T are reduced in VI; T is increased in V4 to V6.

There has been slight forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL. W.K.

Age 2I years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an Rs pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has diphasic P and low upright T waves and a qR pattern.

Vertical Rotation.

A: Sitting.

Lead I shows decrease in R and increase in s.
Lead II shows decrease in R; T is decreased.
Lead III has diphasic T.

B: Standing.

Lead I shows decrease in R and increase in s; T is reduced.
Lead II has a qR pattern; P is increased and T is reduced.
Lead III shows increase in R; P is increased; T is flat.

C: 45° head up.

The changes are similar to those in B.

In A,B and C there has been a slight shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in R; T is increased.
Lead II shows increase in s.
Lead III shows reduction in R; T is flat.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

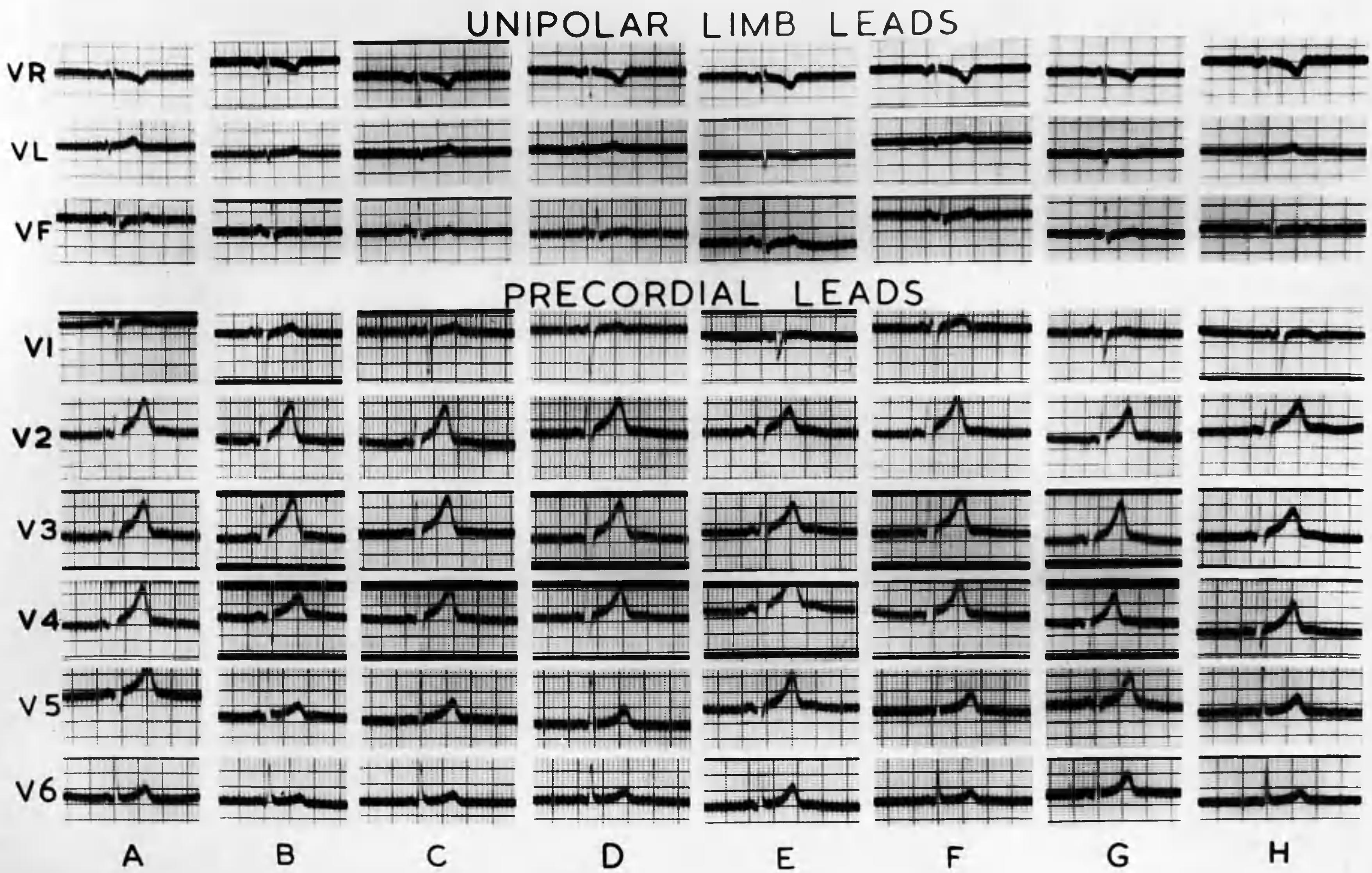
Lead I has an rS pattern; T is reduced.
Lead II shows increase in R.
Lead III shows increase in R; T is increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I has an R pattern.
Lead II shows increase in R; T is increased.
Lead III shows increase in s; T is increased.

G: Prone.

Lead I shows reduction in R and increase in s; T is increased.
Lead II shows decrease in R. Lead III shows increase in s.



UNIPOLAR LIMB LEADS
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PRECORDIAL LEADS
VI
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It tends to face the back of the heart.

VL has flat P and upright T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows reduction in Q and increase in r; T is less inverted.

VL shows increase in S; T is increased.

VF shows increase in R; T is reduced.

B: Standing.

VR shows less inverted T.

VL shows increase in S.

VF shows increase in R; T is reduced.

C: 45° head up.

The changes are similar to those in B.

In A,B and C the heart has become more vertical.

H: 45° head down.

VR shows more deeply inverted T.

VL shows reduction in S; T is increased.

VF shows reduction in R; T is reduced.

The heart has become less vertical.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in Q and increase in r; T is less inverted.

VL has inverted P and T waves and a QS pattern. It now faces the cavity of the left ventricle.

VF shows increase in q,R and s; T is increased.

There has been forward rotation of the apex.

F: Right Lateral.

VR shows increase in Q; T is more deeply inverted.

VL shows reduction in R; T is reduced.

VF shows increase in R and s; T is increased.

G: Prone.

VR shows reduction in Q and increase in r; T is less inverted.

VL has shallow inverted P and T waves and a QS pattern.

VF shows increase in R and s.

The changes are similar to those in E.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns; P and T are upright.
V4 has an Rs pattern; P and T are upright.
V5 and V6 have qR patterns; P and T are upright.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns with reduction in r.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qR pattern.

B: Standing.

VI to V3 have rS patterns.
V4 has an Rs pattern with increase in s.
V5 has an Rs and V6 a qR pattern with increase in R.
T is increased in VI and decreased in V4 to V6.

C: 45° head up.

The patterns are similar to those in B but there is less reduction of T.

In A,B and C there has been further clockwise rotation and the heart has become more vertical.

H: 45° head down.

The patterns are similar to the control but T is reduced in VI to V3 and R is reduced in V6.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns with reduction of S in VI and of r in V2 and V3.
V4 has an RS pattern.
V5 has a qRs pattern with increase in R and s.
V6 has a qR pattern with increase in q and R.
T is reduced in VI to V3 and increased in V4 to V6.
Displacement to the left has occurred along with forward rotation of the apex.

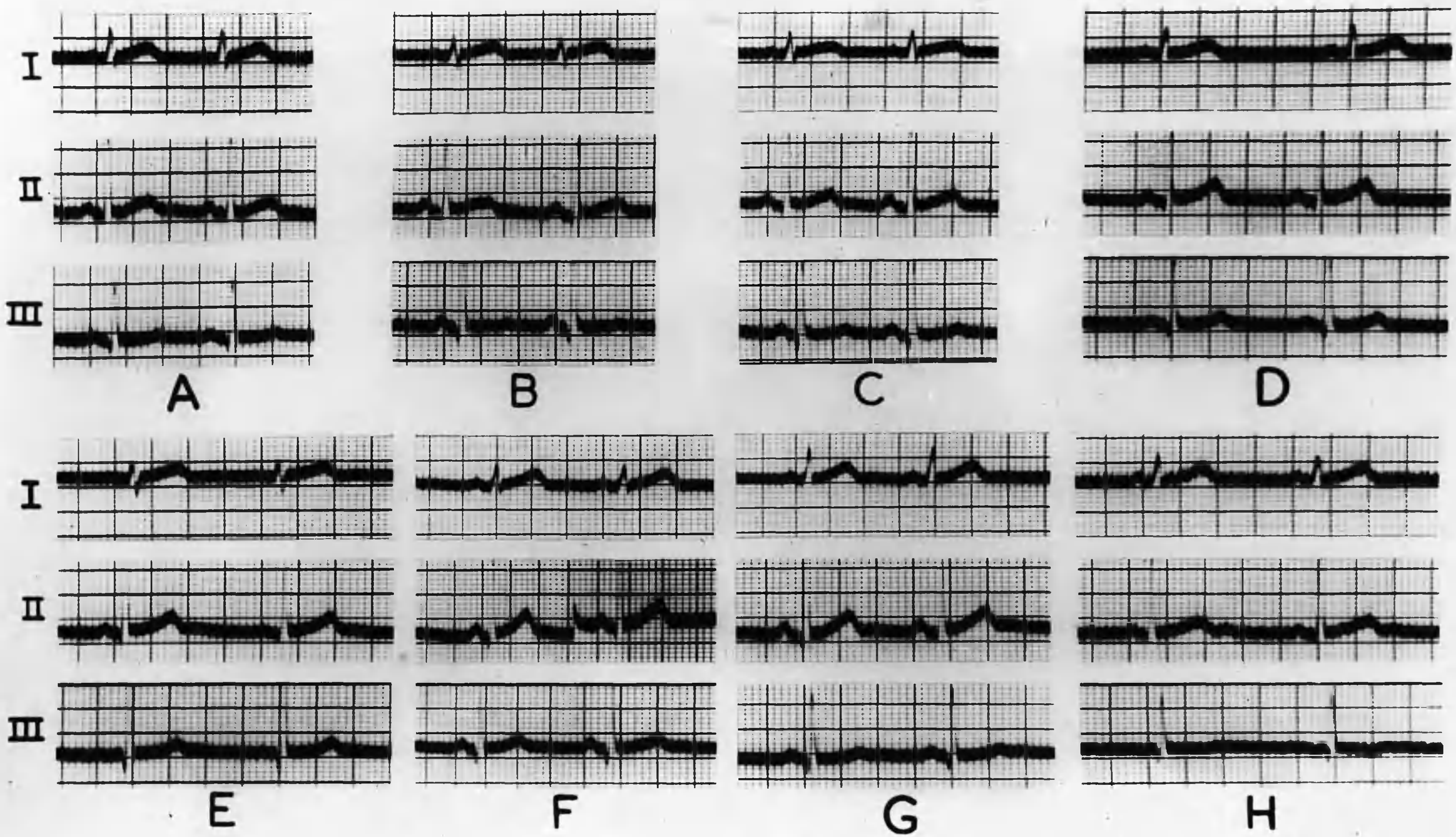
F: Right Lateral.

The patterns are similar to the control but S is increased in VI and R is decreased in V6; T is increased in VI to V3 and reduced in V6.
Displacement to the right has occurred.

G: Prone.

VI to V4 are similar to the control with reduction of S in VI and T in VI and V2. V5 and V6 show changes similar to those in E. The heart has become slightly more horizontal with some forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

G.A.

Age 24 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has an Rs pattern; P and T are upright.
Lead II has a qRs pattern; P and T are upright.
Lead III has a qR pattern; P and T are upright.

Vertical Rotation.

A: Sitting.
Lead I shows increase in R and s.
Lead II shows decrease in T.
Lead III shows decrease in R; T is reduced.

B: Standing.
Lead I has an RS pattern with reduction in R.
Lead II shows reduction in T; P is increased.
Lead III shows increase in q and R; T is flat; P is increased.
There has been a shift of the QRS axis to the right.

C: 45° head up.
The changes are similar to those in B but are less marked.

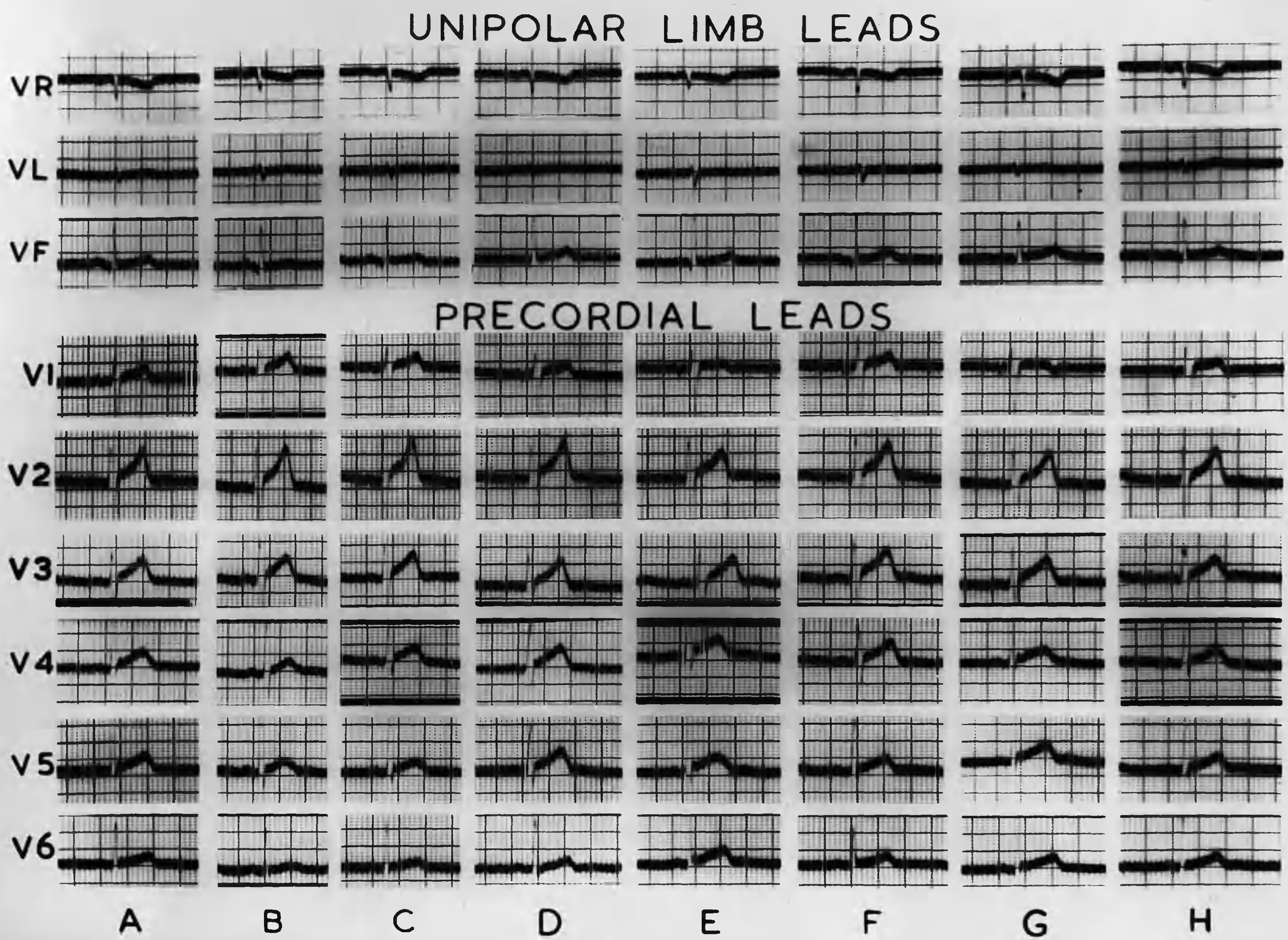
H: 45° head down.
Lead I shows increase in R; T is increased.
Lead II shows reduction in P and T.
Lead III shows reduction in R; P and T are flat.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.
Lead I has an RS pattern with reduction in R; P is reduced.
Lead II shows increase in R; P is reduced.
Lead III shows increase in q and R; P is reduced.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead I shows reduction in R; T is increased.
Lead II shows increase in R; P and T are increased.
Lead III shows increase in q and R.

G: Prone.
Lead I shows increase in R; T is increased.
Lead II shows increase in R.
Lead III shows increase in q; T is reduced.
There has been a shift of the QRS axis to the left.



UNIPOLAR LIMB LEADS
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PRECORDIAL LEADS
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VL has low upright P and T waves and a small RS pattern. It faces the epicardial surface of the right ventricle.

VF has flat P and upright T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VL shows increase in R and S; T is increased.
VF shows upright P; T is reduced.

B: Standing.

VR has a Qr pattern; T is less inverted. It faces the back of the heart.
VL shows increase in S; T is increased.
VF has upright P; q is increased; T is reduced.

C: 45° head up.

VR shows less inverted T.
VL shows increase in R and S.
VF shows upright P; T is reduced.

In A, B and C the heart has probably become more vertical.

H: 45° head down.

VR has a deeper QS; T is more deeply inverted.
VL shows increase in R; T is increased.
VF shows decrease in R; T is reduced.
The heart has become less vertical.

Horizontal Rotation.

E: Left Lateral.

VR has a smaller QS.
VL has an rS pattern.
VF shows increase in q and R; T is reduced.

F: Right Lateral.

VR has a deeper QS.
VL has an rS pattern.
VF shows increase in q.

G: Prone.

VR has a deeper QS; T is more deeply inverted.
VL shows increase in R; T is increased.
VF shows decrease in R.
The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 and V5 have Rs patterns.
V6 has a qRs pattern.
P is diphasic in VI and V2 and upright in all other leads.
T is upright in all leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control but there is reduction of T in V4 to V6.

B: Standing.

The patterns are similar to the control but R is increased in V4 and V5 and reduced in V6.
T is increased in VI and reduced in V3 to V6.

C: 45° head up.

The patterns are similar to those in B.

In A, B and C the heart has probably become more vertical.

H: 45° head down.

The patterns are similar to the control but R is increased in V4 to V6 and s is reduced.
There has been slight counter-clockwise rotation.

Horizontal Rotation.

E: Left Lateral.

The patterns are similar to the control but R is increased in V4 to V6; T is reduced in VI to V5 and increased in V6.
Displacement to the left has occurred.

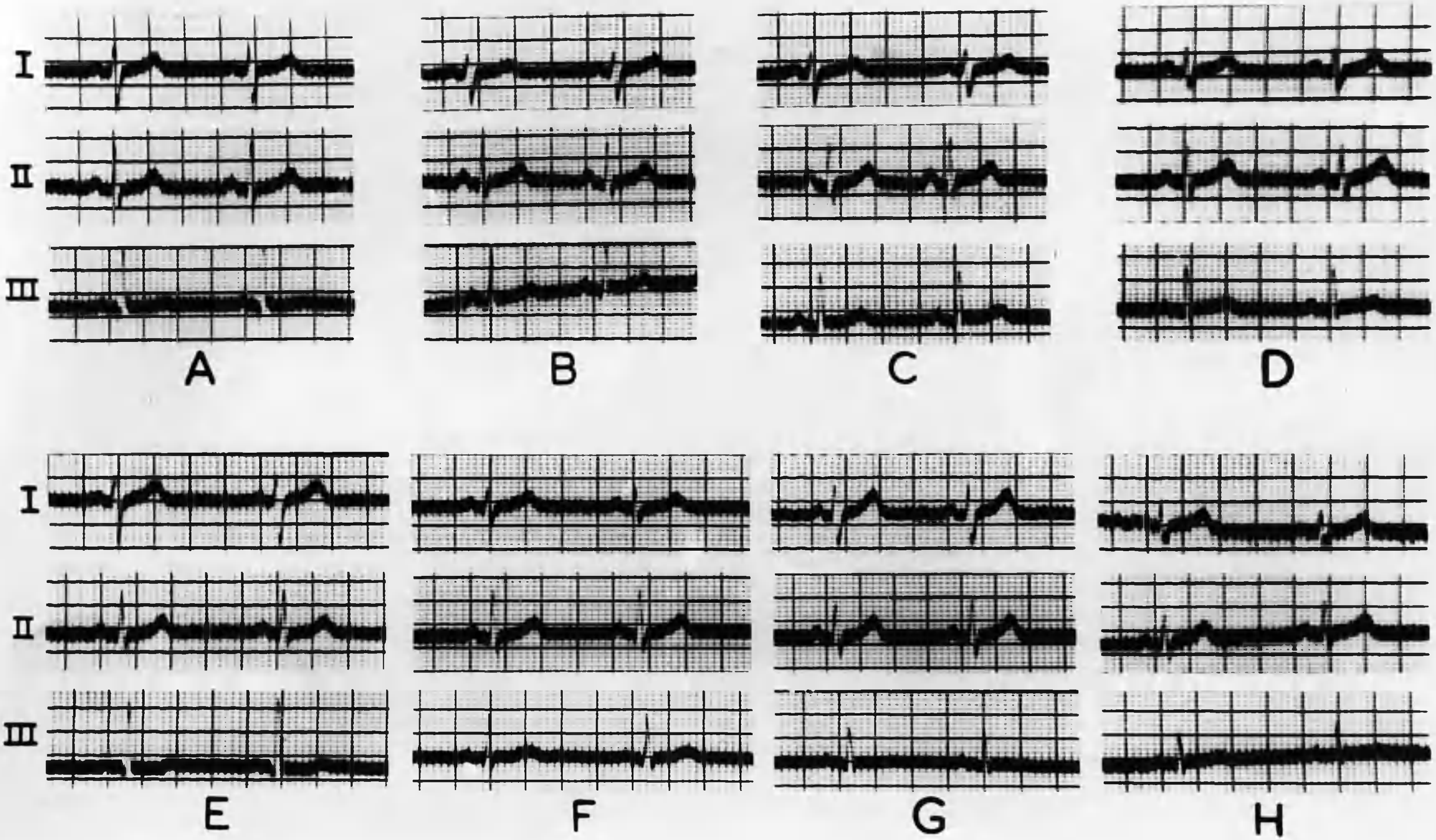
F: Right Lateral.

The patterns are similar to the control but r is increased in VI to V3; s is reduced in V5 and V6; R is reduced in V6; T is reduced in V5 and V6.
Displacement to the right has occurred.

G: Prone.

The patterns are similar to the control but R is increased and s is reduced in V4 to V6; T is reduced in VI to V4 and increased in V6.
The heart has probably become more horizontal, with some forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

S.N.

Age I5 years

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an RS pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has upright P and T waves and a qRs pattern.
There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I shows increase in S.
Lead II shows increase in R; P is increased and T is reduced.
Lead III has a qR pattern with increase in R; P is increased and T is reduced.

B: Standing.

Lead I shows reduction in R and increase in S; T is reduced.
Lead II shows increase in R and reduction in s; P is increased and T is reduced.
Lead III has a qR pattern with increase in R; P is increased and T is reduced.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A,B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows reduction in S.
Lead II shows reduction in R; T is reduced.
Lead III has an Rs pattern with reduction in R; P and T are reduced.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

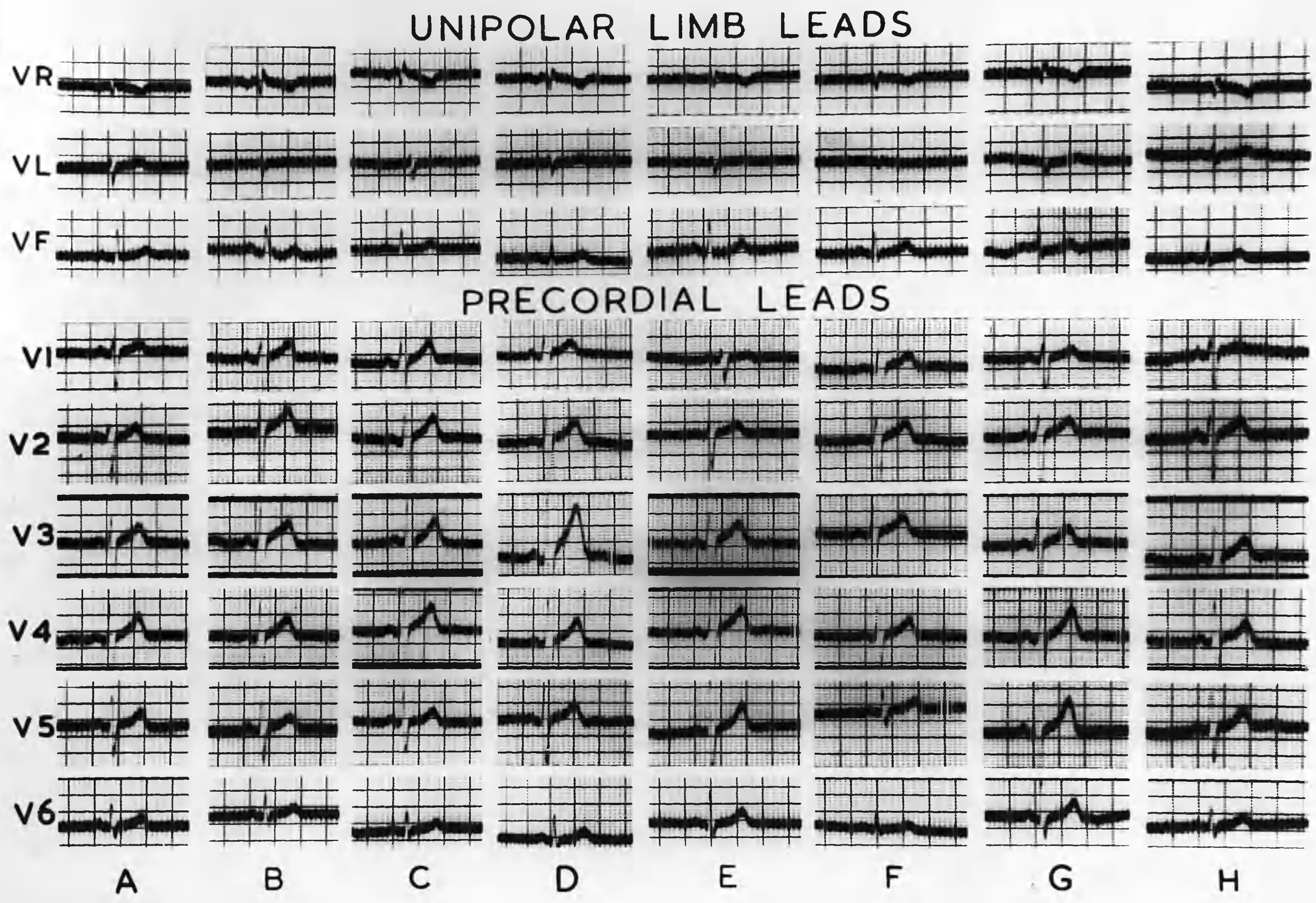
Lead I shows increase in S; T is increased.
Lead II shows reduction in s; T is reduced.
Lead III has a qR pattern with increase in q and R; T is reduced.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows reduction in R and S; T is reduced.
Lead II shows increase in R; T is reduced.
Lead III shows increase in R and s.

G: Prone.

Lead I shows increase in R and S; T is increased.
Lead III shows decrease in R; P is diphasic and T is flat.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
VI
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a QR pattern. It faces the back of the heart.

VL has upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows reduction in Q.
VL shows increase in S.
VF shows increase in R.

B: Standing.

VR shows increase in R.
VL has flat P and T waves and a QS pattern.
VF shows increase in R.

C: 45° head up.

VR shows increase in R.
VL shows increase in S; T is reduced.
VF shows increase in R; T is reduced.

In A,B and C the heart has become more vertical.

H: 45° head down.

VL has an Rs pattern; T is increased.
VF has an Rs pattern.
The heart has become less vertical.

Horizontal Rotation.

E: Left Lateral.

VR has an rSr' pattern; P and T are less inverted. It faces the epicardial surface of the right ventricle.

VL shows increase in S; T is reduced.
VF shows increase in R and T.

F: Right Lateral.

VR has an rSr' pattern; P and T are less inverted.
VL has an rsr' pattern; P and T are flat.
VF shows increase in R,s and T.

G: Prone.

VL shows increase in T.
VF shows increase in R and s.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have rS patterns; P and T are upright.
V3 to V5 have RS patterns; P and T are upright.
V6 has a qRs pattern; P and T are upright.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns.
V4 and V5 have RS patterns.
V6 has a qRs pattern.
T is reduced in all leads.

B: Standing.

The patterns are similar to those in A.

C: 45° head up.

The patterns are similar to those in A and B.

In A,B and C there has been further clockwise rotation.

H: 45° head down.

VI to V3 have rS patterns.
V4 and V5 have RS patterns.
V6 has a qRs pattern with reduction in R and increase in s.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns with reduction in r and S.
V4 and V5 have RS patterns with increase in R.
V6 has a qRs pattern with increase in q,R and s.
T is reduced in VI to V3 and increased in V4 to V6.
Displacement to the left has occurred with forward rotation of the apex.

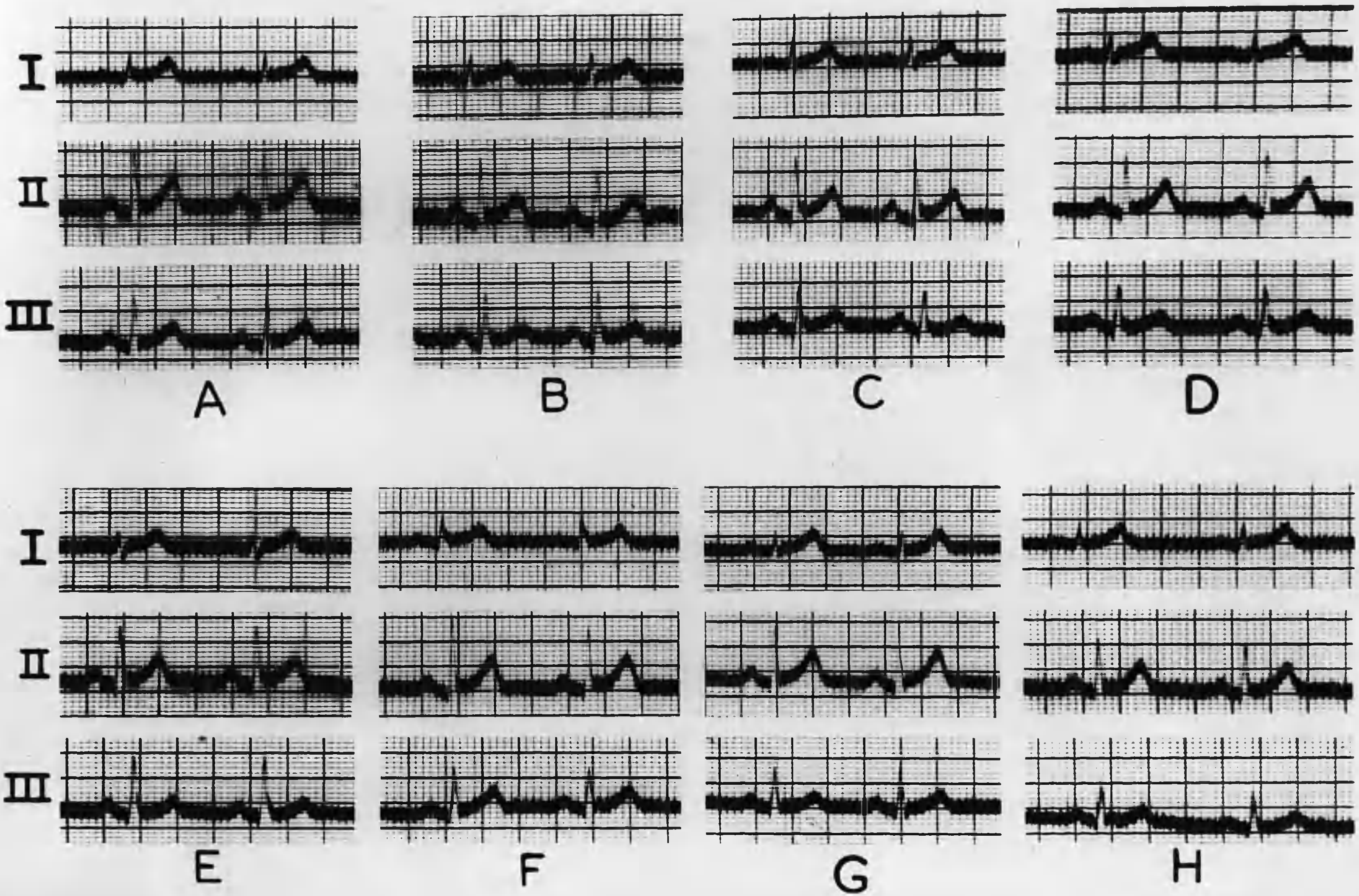
F: Right Lateral.

VI to V3 have rS patterns.
V4 has an RS pattern with reduction in R and S.
V5 has an Rs pattern with reduction in R.
V6 has a qRs pattern with reduction in q,R and s.
T is reduced in V4 to V6.
Displacement to the right has occurred with backward rotation of the apex.

G: Prone.

VI and V2 are similar to the control. V3 to V6 are similar to E. Forward rotation of the apex has occurred.

STANDARD LIMB LEADS



NORMAL.

A.B.

Age 21 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an Rs pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has upright P and T waves and a qR pattern.

Vertical Rotation.

A: Sitting.

Lead II shows increase in R; P is increased; T is increased.
Lead III has a qRs pattern with increase in R; P is increased; T is increased.

B: Standing.

Lead II shows increase in P; T is reduced.
Lead III shows increase in R; P is increased; T is reduced.

C: 45° head up.

The changes are similar to those in B.

In A, B and C there has been a slight shift of the QRS axis to the right.

H: 45° head down.

Lead I has an R pattern.
Lead II shows reduction in R.
Lead III shows reduction in R.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

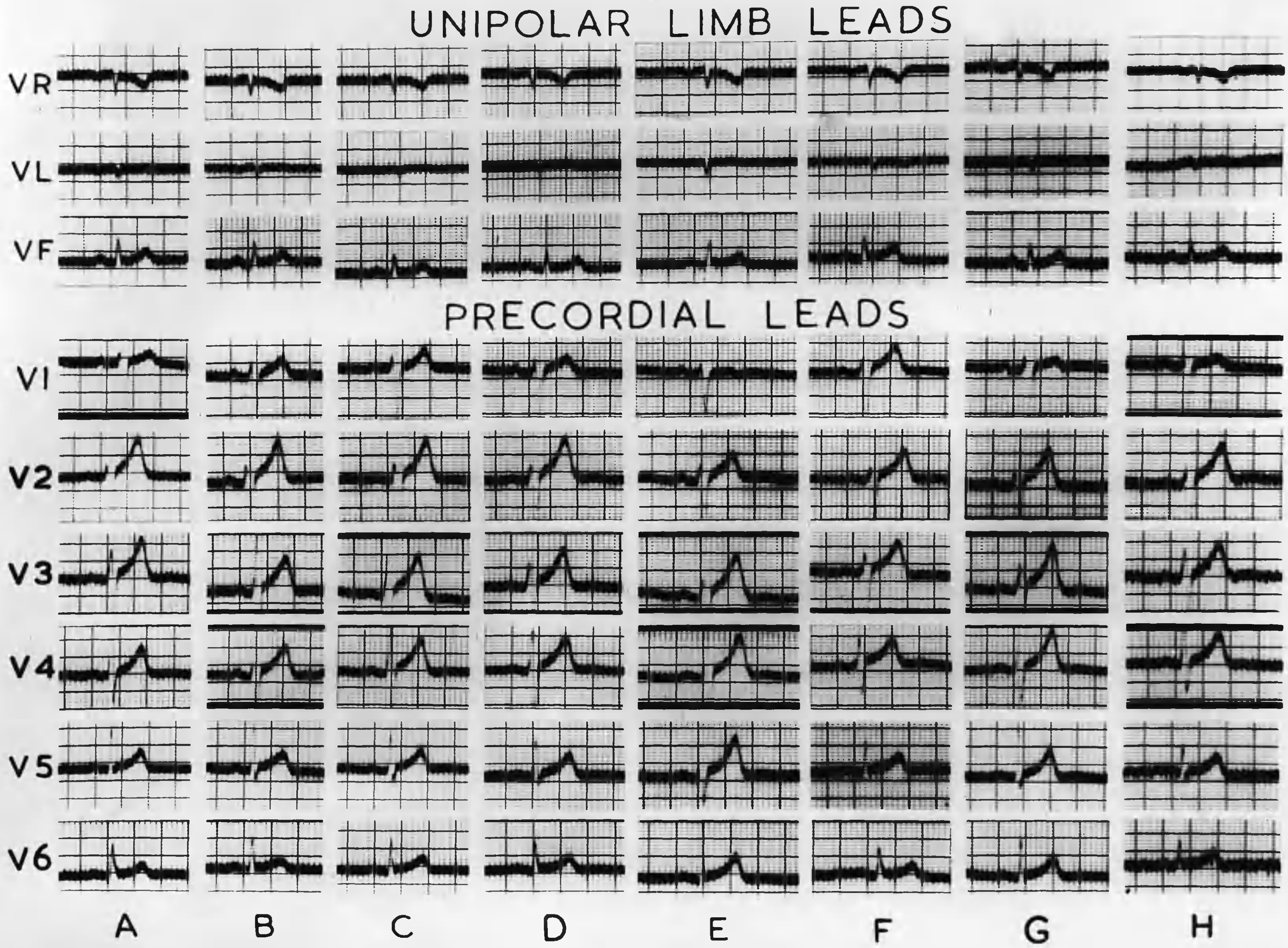
Lead I has an rS pattern.
Lead III shows increase in R.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I has a qR pattern with increase in R.
Lead II shows a qR pattern with increase in R; T is increased.
Lead III has a qRs pattern; T is increased.
There has been a shift of the QRS axis to the left.

G: Prone.

Lead I shows reduction in R and s; T is increased.
Lead II shows increase in R and s; T is increased.
Lead III has a qRs pattern with reduction in R.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
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C
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F
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H

UNIPOLAR LIMB LEADS.

D: Supine.
VR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.
VL has inverted P and low upright T waves and an rS pattern. It faces the epicardial surface of the right ventricle.
VF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.
The heart is vertical.

Vertical Rotation.
A: Sitting.
VR has deeper QS; T is more inverted.
VL has a qs pattern.
VF has a qRs pattern with increase in R.

B: Standing.
VL shows more inverted P.
VF shows increase in P; T is reduced.

C: 45° head up.
The changes are similar to those in B.

H: 45° head down.
VR shows more deeply inverted T.
VL shows increase in T.
VF shows reduction in R.

Horizontal Rotation.
E: Left Lateral.
VR has an rS pattern; T is more inverted. It faces the cavity of the right ventricle.
VL shows increase in S.
VF shows increase in R.

F: Right Lateral.
VR has an rS pattern; T is more inverted.
VL shows inversion of T.
VF shows increase in T.

G: Prone.
VR has an rS pattern; T is more inverted.
VL has an rSr' pattern.
VF has a qRs pattern.
The heart has probably become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns; P and T are upright.
V4 has an RS pattern; P and T are upright.
V5 has a qRs pattern; P and T are upright.
V6 has a qR pattern; P and T are upright.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control.

B: Standing.

The patterns are similar to the control but T is reduced in V3 to V6.

C: 45° head up.

The patterns are similar to the control.

H: 45° head down.

The patterns are similar to the control but R is reduced in V5 and V6; T is reduced in VI and V2.

The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns with reduction in r.
V4 has an RS pattern with increase in R.
V5 and V6 have qRs patterns with increase in R and s.

T is inverted in VI, reduced in V2 and increased in V3 to V6.

Displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

The patterns are similar to the control but R and S are reduced in V4; R and s are reduced in V5; q and R are reduced in V6.

T is increased in VI and reduced in all other leads.

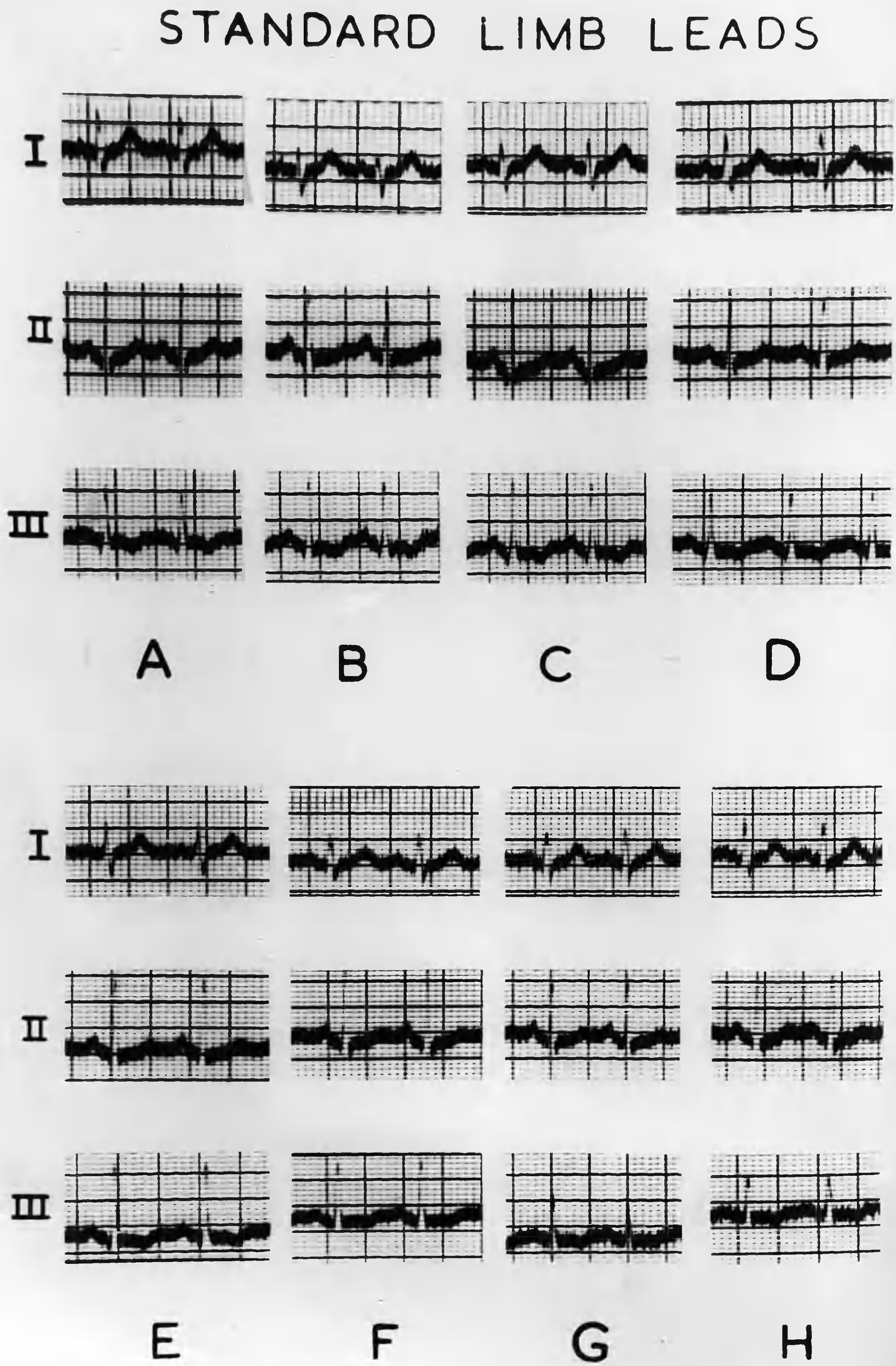
Displacement to the right has occurred.

G: Prone.

VI to V3 have rS patterns.
V4 has an RS pattern with increase in R and reduction in S.

V5 and V6 have qRs patterns with increase in R and s.
T is reduced in VI and V2 and increased in V3 to V6.

The heart has become more horizontal and there has been some forward rotation of the apex.


STANDARD LIMB LEADS
I
II
III
A
B
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D
I
II
III
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G
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NORMAL.

Miss J.F.

Age 17 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an Rs pattern.

Lead II has upright P and T waves and a qRs pattern; the ST segment is slightly depressed.

Lead III has upright P and inverted T waves and a qR pattern; the RT segment is slightly depressed.

There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I shows decrease in R and increase in s; T is increased.

Lead II shows increase in R and s; T is increased.

Lead III shows decrease in R; T is slightly more inverted.

B: Standing.

Lead I has an RS pattern with decrease in R.

Lead II shows increase in P; T is reduced.

Lead III shows increase in R; P is increased; T is more inverted.

There has been a shift of the QRS axis to the right.

C: 45° head up.

The changes are similar to those in B.

H: 45° head down.

Lead I shows decrease in s.

Lead III shows a qRs pattern with decrease in R.

There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

Lead I has an RS pattern with decrease in R.

Lead II shows increase in R; P is increased.

Lead III shows increase in R; P is increased.

There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows decrease in R and s.

Lead II shows increase in R and s.

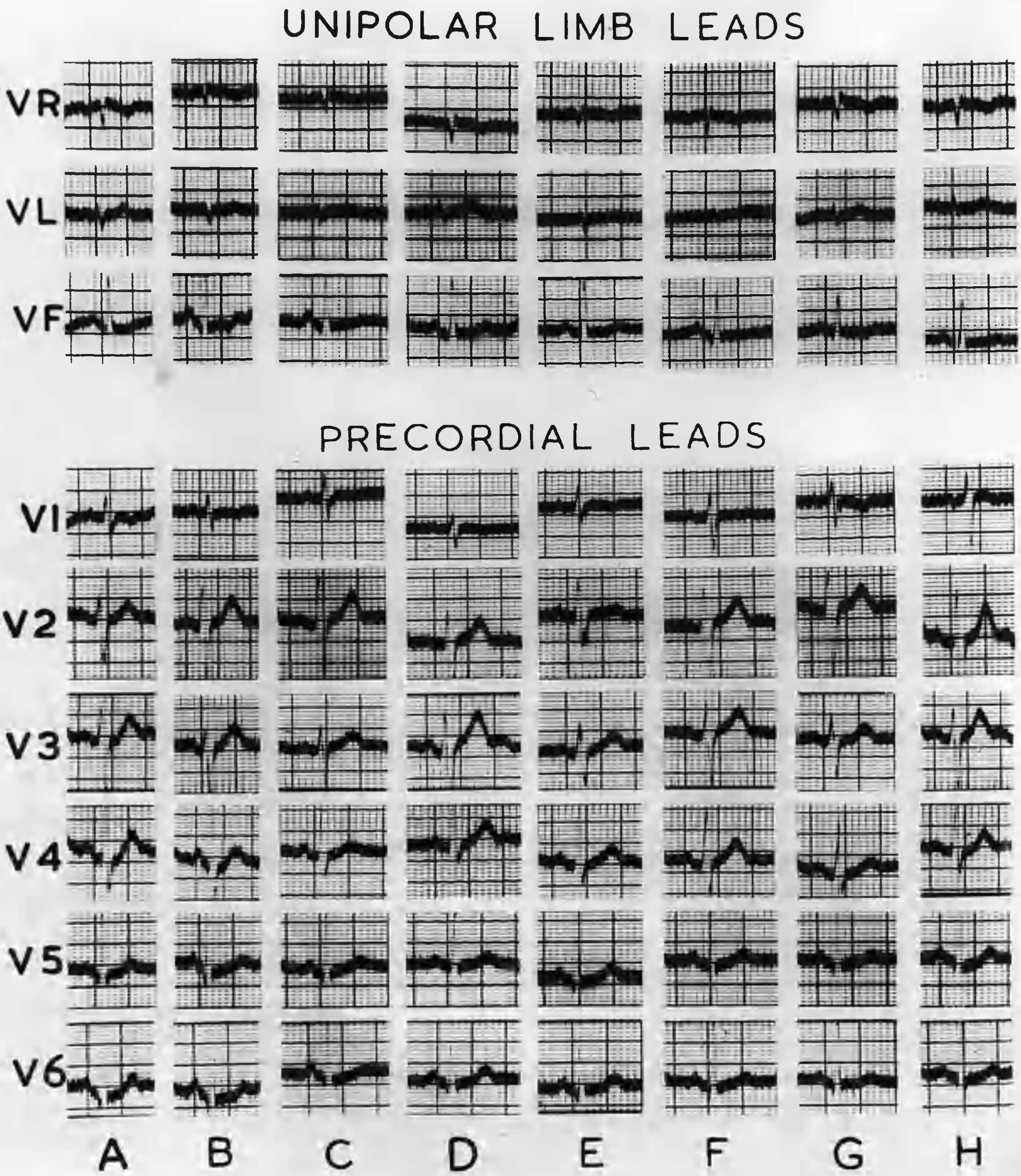
Lead III has a qRs pattern; T is less inverted.

G:.Prone.

Lead I shows decrease in R and s.

Lead III has a qRs pattern with decrease in R.

There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
V1
V2
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VL shows increase in S; T is increased.
VF shows decrease in R; T is reduced.

B: Standing.

VR shows decrease in Q; T is less inverted.
VL has an rS pattern; T is reduced.
VF shows increase in q and R; P is increased; T is inverted.
The heart has become more vertical.

C: 45° head up.

The changes are similar to those in B but are less marked.

H: 45° head down.

VR shows increase in Q.
VL has an Rs pattern with increase in R.
VF has a qRs pattern with reduction in R; T is reduced.
The heart has become less vertical.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in Q; T is less inverted.
VL has an rS pattern with increase in S; T is reduced.
VF shows increase in P.

F: Right Lateral.

VL has an rs pattern; T is reduced.
VF has a qRs pattern with reduction in R; P is increased; T is reduced.

G: Prone.

VR shows increase in r.
VL has an RS pattern with increase in R.
VF shows reduction in q and R; T is slightly inverted.
The heart has become less vertical.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 has an Rs pattern.
V5 and V6 have qRs patterns.
P is upright in all leads. T is flat in VI and upright in all other leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI has an RS pattern; T is inverted.
V2 and V3 have rS patterns with reduction in r.
V4 has an Rs pattern with increase in s.
V5 and V6 have qRs patterns with increase in q.

B: Standing.

VI has an RS pattern.
V2 and V3 have rS patterns.
V4 to V6 have qRs patterns with increase of q in V5 and V6.
P is increased in V4 to V6. T is reduced in V3 to V6.

C: 45° head up.

The patterns are similar to those in B.

In B and C the heart has probably become more vertical.

H: 45° head down.

The patterns are similar to the control but r and S are increased in VI and V2; s is increased in V4 to V6; T is increased in VI and V2 and decreased in V6.
The heart has probably become less vertical.

Horizontal Rotation.

E: Left Lateral.

VI and V2 have splintered RS patterns.
V3 has an RS pattern.
V4 has an Rs pattern.
V5 and V6 have qRs patterns with increase in q and R.
T is reduced in VI to V3 and increased in V5 and V6.
Displacement to the left has occurred with some forward rotation of the apex.

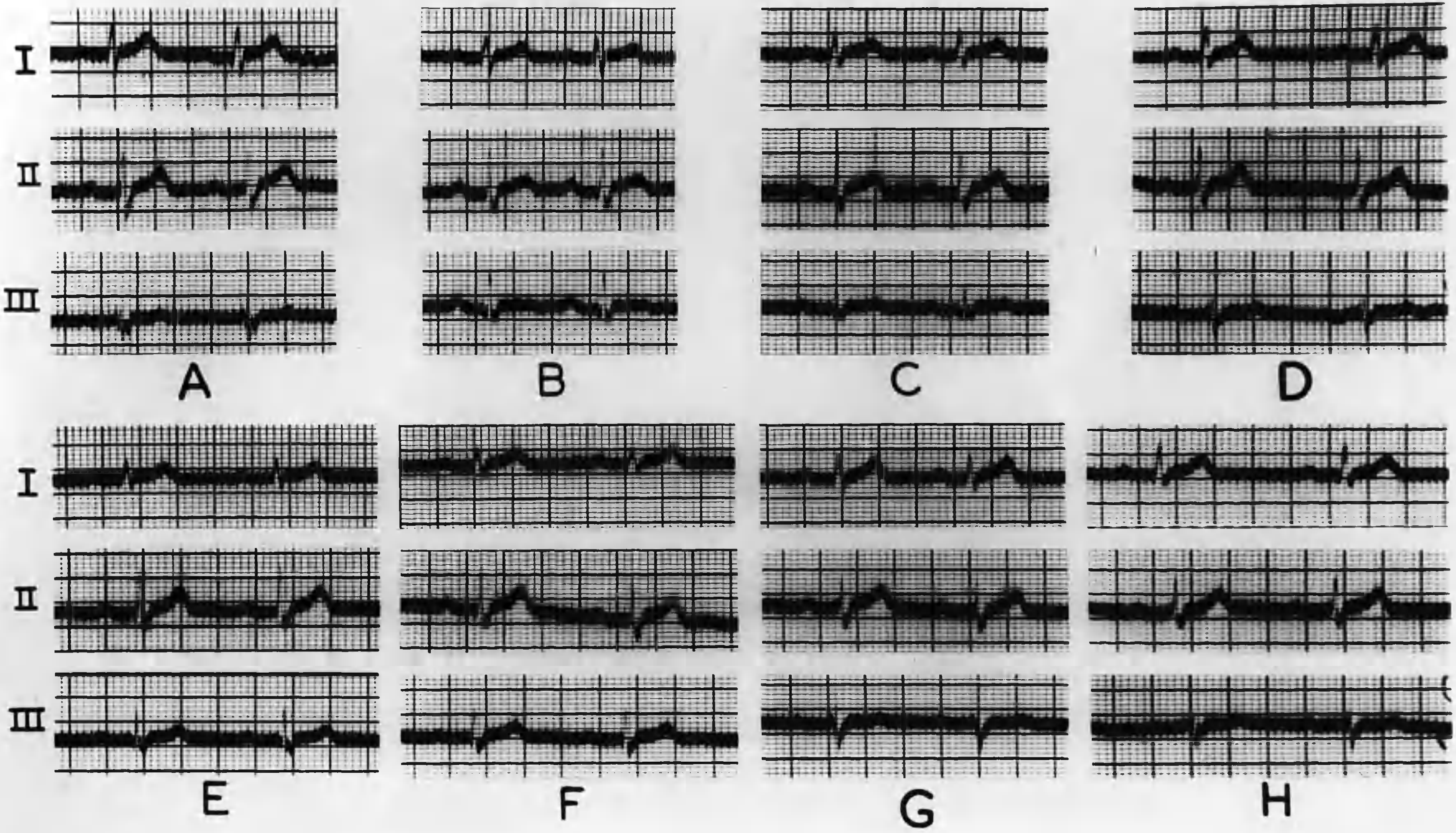
F: Right Lateral.

The patterns are similar to the control but r and S are increased in VI; T is flat in VI and reduced in V5 and V6.
Some displacement to the right has occurred.

G: Prone.

The patterns are similar to the control but in VI r and S are increased and T is inverted; in V3 r and S are reduced; T is reduced in V3 to V6.
The heart has probably become more horizontal.

STANDARD LIMB LEADS



NORMAL. J.I.

Age 23 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and a qRs pattern.
Lead II has upright P and T waves and an Rs pattern.
Lead III has upright P and T waves and an rsR'S' pattern.

Vertical Rotation.

A: Sitting.

Lead I shows increase in s; T is increased.
Lead II shows increase in s.
Lead III shows decrease in T.

B: Standing.

Lead I has an RS pattern with reduction in R; T is reduced.
Lead II has a qRs pattern with increase in R; P is increased; T is reduced.
Lead III has a qRs pattern; P is increased; T is reduced.

C: 45° head up.

The changes are similar to those in B but are less marked.

In B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows reduction in s.
Lead II shows reduction in R and s; T is reduced.
Lead III shows reduction in R'.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

Lead I shows reduction in R; T is reduced.
Lead II has a qRs pattern with increase in R and reduction in s.
Lead III has a qRs pattern; T is increased.
There has been a shift of the QRS axis to the right;

F: Right Lateral.

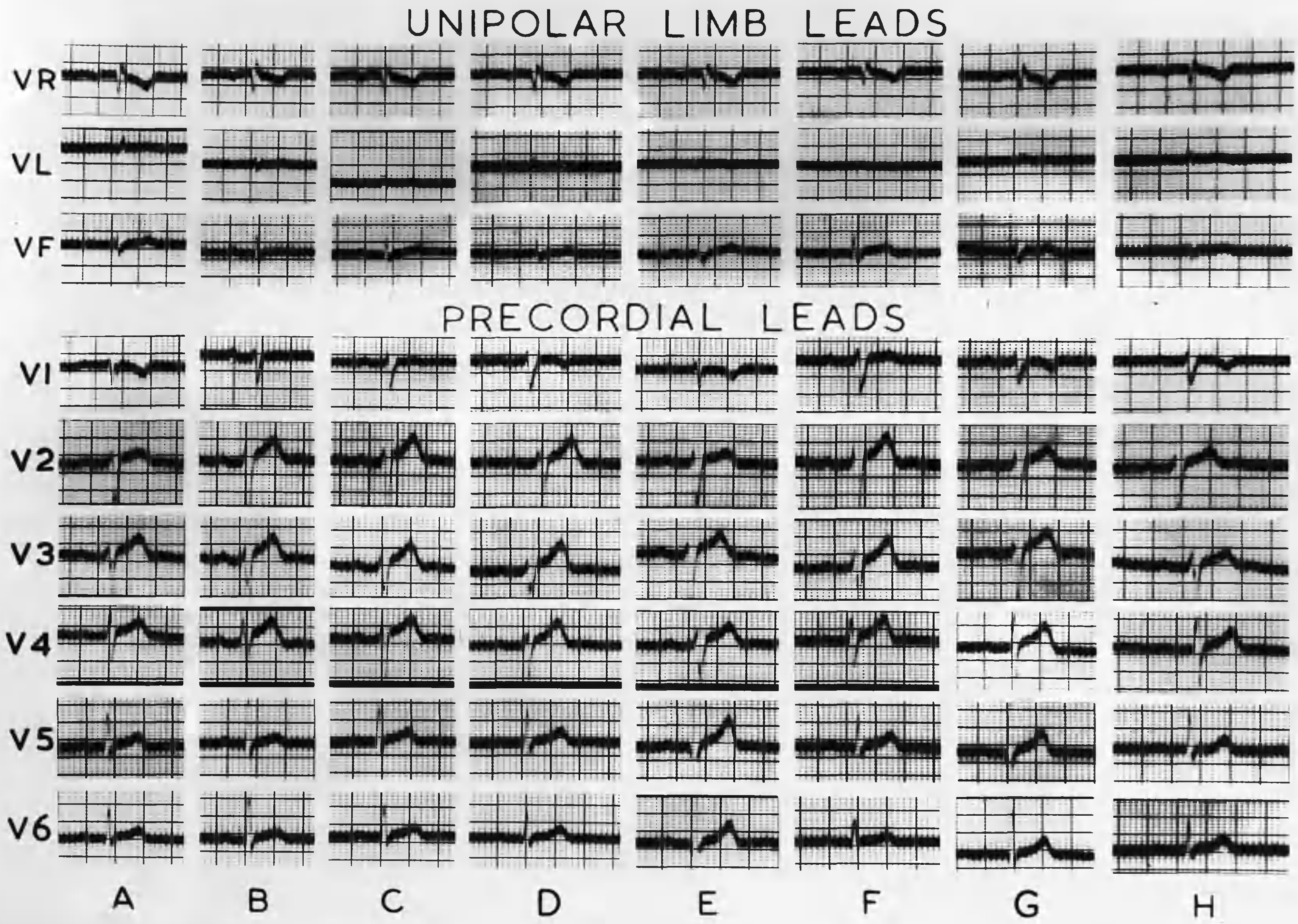
Lead I shows reduction in R and s; T is reduced.
Lead II has a qRs pattern; T is increased.
Lead III has a qRs pattern; T is increased.
There has been a shift of the QRS axis to the right.

G: Prone.

Lead I shows reduction in R.

Lead II shows reduction in R; T is reduced.

Lead III shows reduction in R' and increase in S'; T is reduced.


UNIPOLAR LIMB LEADS
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PRECORDIAL LEADS
VI
V2
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and T waves and a small splintered r pattern.

VF has upright P and T waves and a qrs pattern.

The position of the heart is difficult to determine but it is probably vertical.

Vertical Rotation.

A: Sitting.

VR shows increase in Q and r; T is more inverted.

VL has a splintered qrs pattern.

VF has an rsr's' pattern; T is increased.

B: Standing.

VR shows increase in r; T is less inverted.

VL has an rs pattern.

VF has a qRs pattern; P is increased; T is reduced.

The heart is vertical.

C: 45° head up.

The patterns are similar to those in B.

H: 45° head down.

VL has an rs pattern; T is increased.

VF has a qrs pattern.

Horizontal Rotation.

E: Left Lateral.

VL has an rsr' pattern; T is slightly inverted.

VF has a qRs pattern; T is increased.

The heart is vertical.

F: Right Lateral.

VR shows reduction in Q; T is less inverted.

VL has an rsr' pattern; T is flat.

VF has a qRs pattern; T is increased.

The heart is vertical.

G: Prone.

VR shows reduction in Q and increase in r; T is more inverted.

VL has an rsr's' pattern.

VF has an rsR'S' pattern; T is increased.

PRECORDIAL LEADS.

D: Supine.

VI to V4 have rS patterns.
V5 and V6 have qRs patterns.
P is upright in all leads.
T is slightly inverted in VI and upright in all other leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI has a splintered rS pattern with reduction in S.
V2 and V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns.
T is more inverted in VI and is reduced in V2 to V4.

B: Standing.

VI to V4 have rS patterns.
V5 and V6 have qRs patterns with increase in R and s.
T is less inverted in VI but is reduced in V2,V3,V5 and V6.
P is increased in all leads.

C: 45° head up.

The patterns are similar to the control.

H: 45° head down.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns
T is more inverted in VI and is reduced in V2 and V3.
The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V4 have rS patterns with reduction of S in VI and V2. V5 and V6 have qRs patterns with increase in q, R and s. T is more inverted in VI, reduced in V2 to V4 and increased in V5 and V6. Displacement to the left has occurred with forward rotation of the apex.

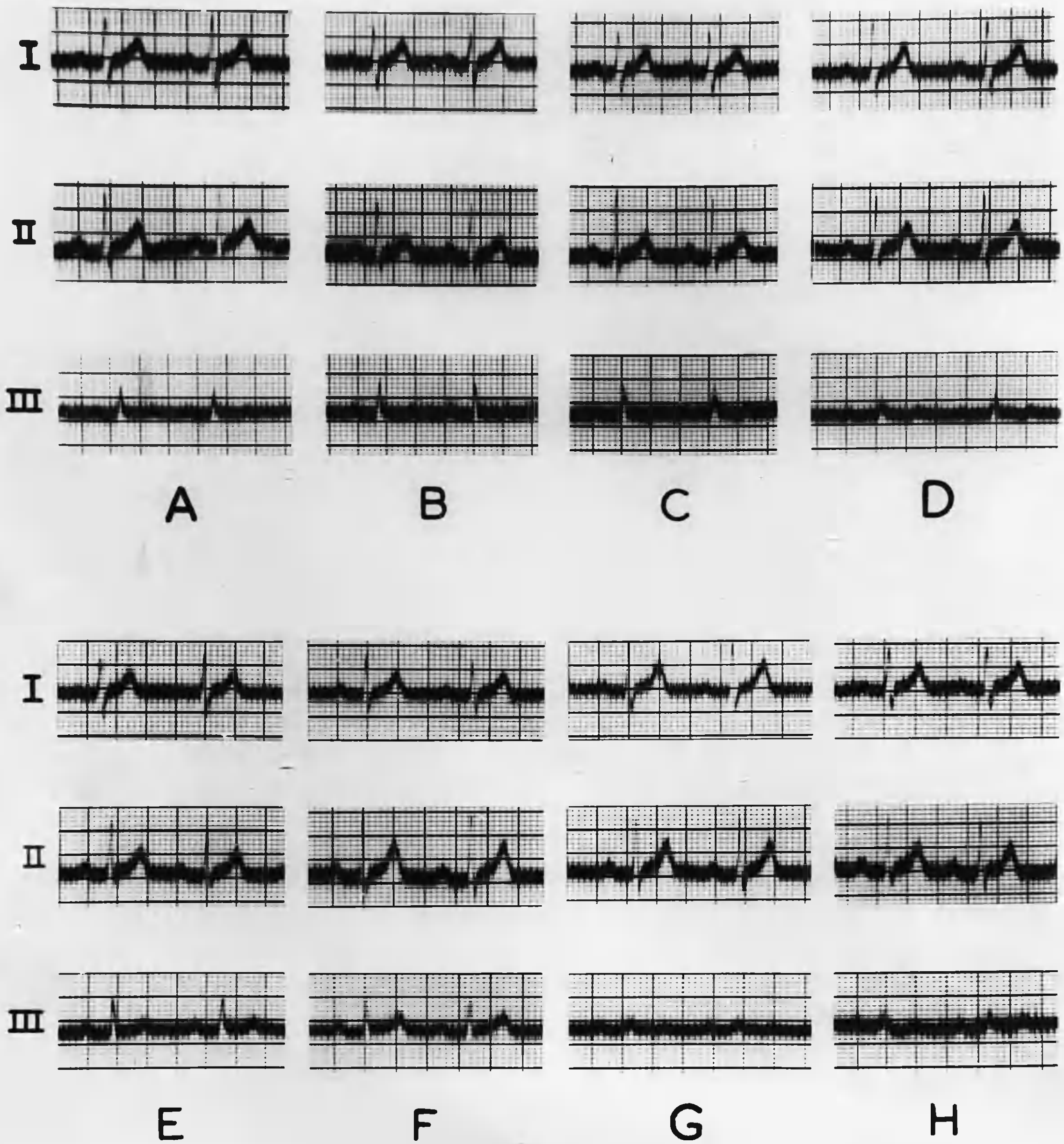
F: Right Lateral.

VI to V3 have rS patterns with increase in r and S. V4 has an RS pattern. V5 and V6 have qRs patterns with reduction in R and s. T is increased in VI to V3 and reduced in V6. Displacement to the right has occurred.

G: Prone.

VI to V3 have rS patterns with reduction of S. V4 has an RS pattern. V5 and V6 have qRs patterns with increase in q,R and s. T is reduced in VI to V3 and increased in V5 and V6. The heart has become more horizontal with forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

W.M.

Age I8 years.

STANDARD LIMB LEADS.

D: Supine.

Leads I and II have upright P and T waves and Rs patterns.

Lead III has upright P and slightly diphasic T waves and an R pattern.

Vertical Rotation.

A: Sitting.

Lead I shows reduction in R and increase in s; T is reduced.

Lead II shows increase in R; T is reduced.

Lead III shows increase in R; T is practically flat.

B: Standing.

Lead I has an RS pattern with reduction in R; T is reduced.

Lead II shows reduction in R; T is reduced.

Lead III shows increase in R; T is slightly inverted.

C: 45° head up.

The changes are similar to those in B.

In A, B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows reduction in R and s.

Lead II shows reduction in R.

Lead III has a small splintered R pattern of reduced amplitude.

Horizontal Rotation.

E: Left Lateral.

Lead I has an RS pattern with reduction in R; T is reduced.

Lead II shows reduction in R.

Lead III shows increase in R; T is upright.

There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows reduction in R and s; T is reduced.

Lead II shows increase in R; T is increased.

Lead III shows increase in R; T is upright and of increased amplitude.

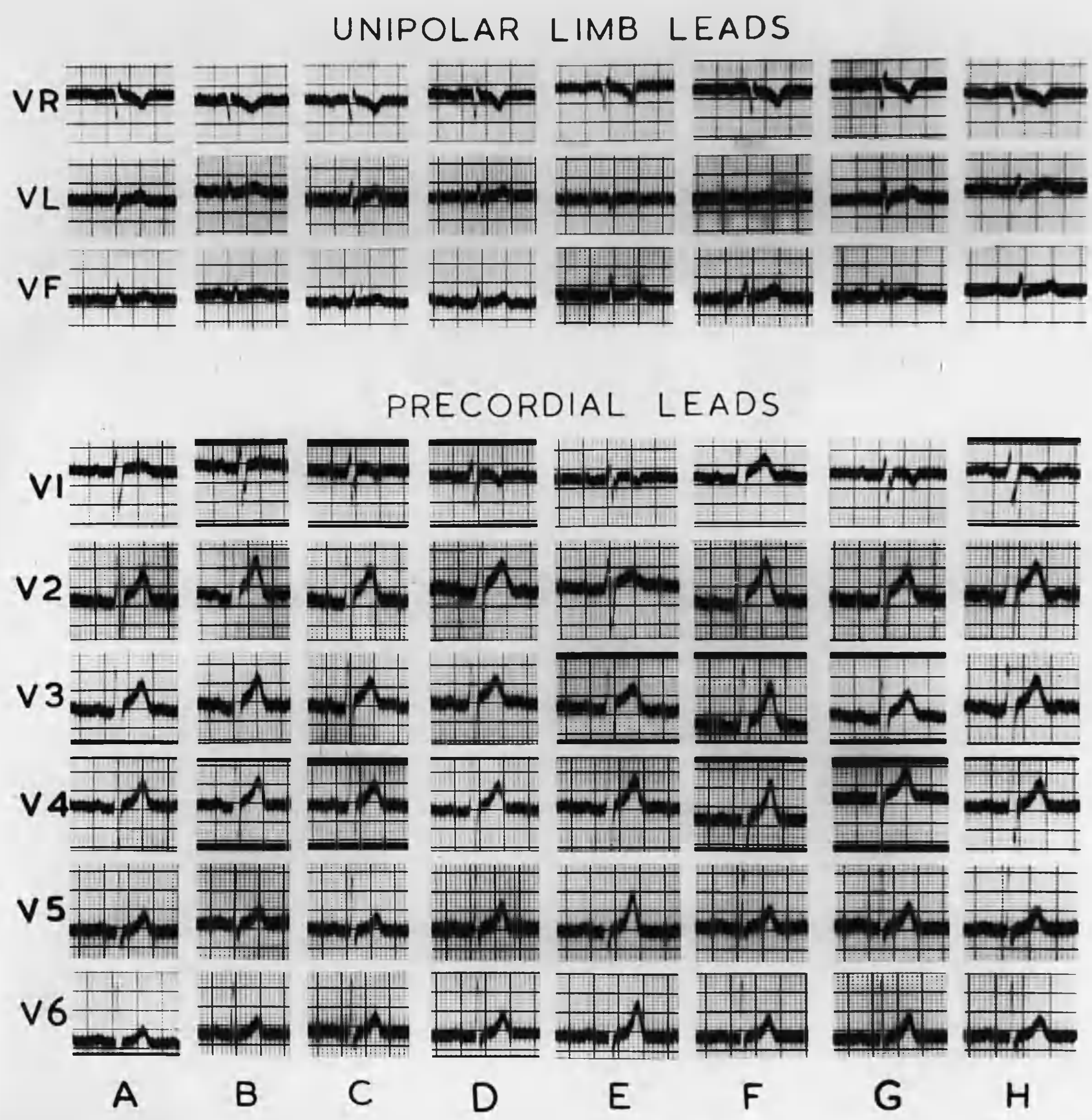
G: Prone.

Lead I shows increase in T.

Lead II shows increase in s; T is increased.

Lead III has a small splintered R pattern of reduced amplitude; T is diphasic and less positive.

There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
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PRECORDIAL LEADS
VI
V2
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is vertical with backward rotation of the apex.

Vertical Rotation.

A: Sitting.

VL has an RS pattern; T is increased.
VF has an R pattern; T is reduced.

B: Standing.

VR shows reduction in Q and r; T is less inverted.
VL shows reduction in R and s.
VF shows reduction in R and s; T is reduced.

C: 45° head up.

VL has an RS pattern; T is increased.
VF shows reduction in R and s; T is reduced.

H: 45° head down.

The patterns are similar to the control.

Horizontal Rotation.

E: Left Lateral.

VR shows decrease in Q and r; T is less inverted.
VL has an rS pattern; T is reduced.
VF shows increase in R and reduction in s; T is increased.

F: Right Lateral.

VR shows reduction in r.
VL has an rs pattern; T is reduced.
VF shows increase in R; T is increased.

G: Prone.

VR shows increase in r; T is more inverted.
VL has an RS pattern with increase in R; T is increased.
VF shows reduction in R and s.

PRECORDIAL LEADS.

D: Supine.

VI has a splintered rS pattern; P is upright; T is inverted.
V2 and V3 have rS patterns; P and T are upright.
V4 has an RS pattern; P and T are upright.
V5 and V6 have qRs patterns; P and T are upright.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control but in VI S is not splintered and T is upright; in V5 and V6 s is increased and T is reduced.

B: Standing.

The patterns are similar to the control but R is reduced in V5 and V6; T is flat in VI, increased in V2 and reduced in V5 and V6.

The heart has probably become more vertical.

C: 45^{o} head up.

The patterns are similar to the control but R and T are reduced in V5 and V6.

H: 45^{o} head down.

VI to V3 have rS patterns.
V4 has an Rs pattern.
V5 and V6 have qRs patterns.
There has been slight counter-clockwise rotation.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns with reduction of r in VI and V2 and reduction of S in V2 and V3.

V4 has an RS pattern.

V5 and V6 have qRs patterns with increase in q,R and s.

T is less inverted in VI, reduced in V2 and V3 and increased in V4 to V6.

Displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

VI to V3 have rS patterns with increase in r and S.

V4 has an Rs pattern.

V5 and V6 have qRs patterns.

T is upright in VI, increased in V2 to V4 and reduced in V5 and V6.

Displacement to the right has occurred.

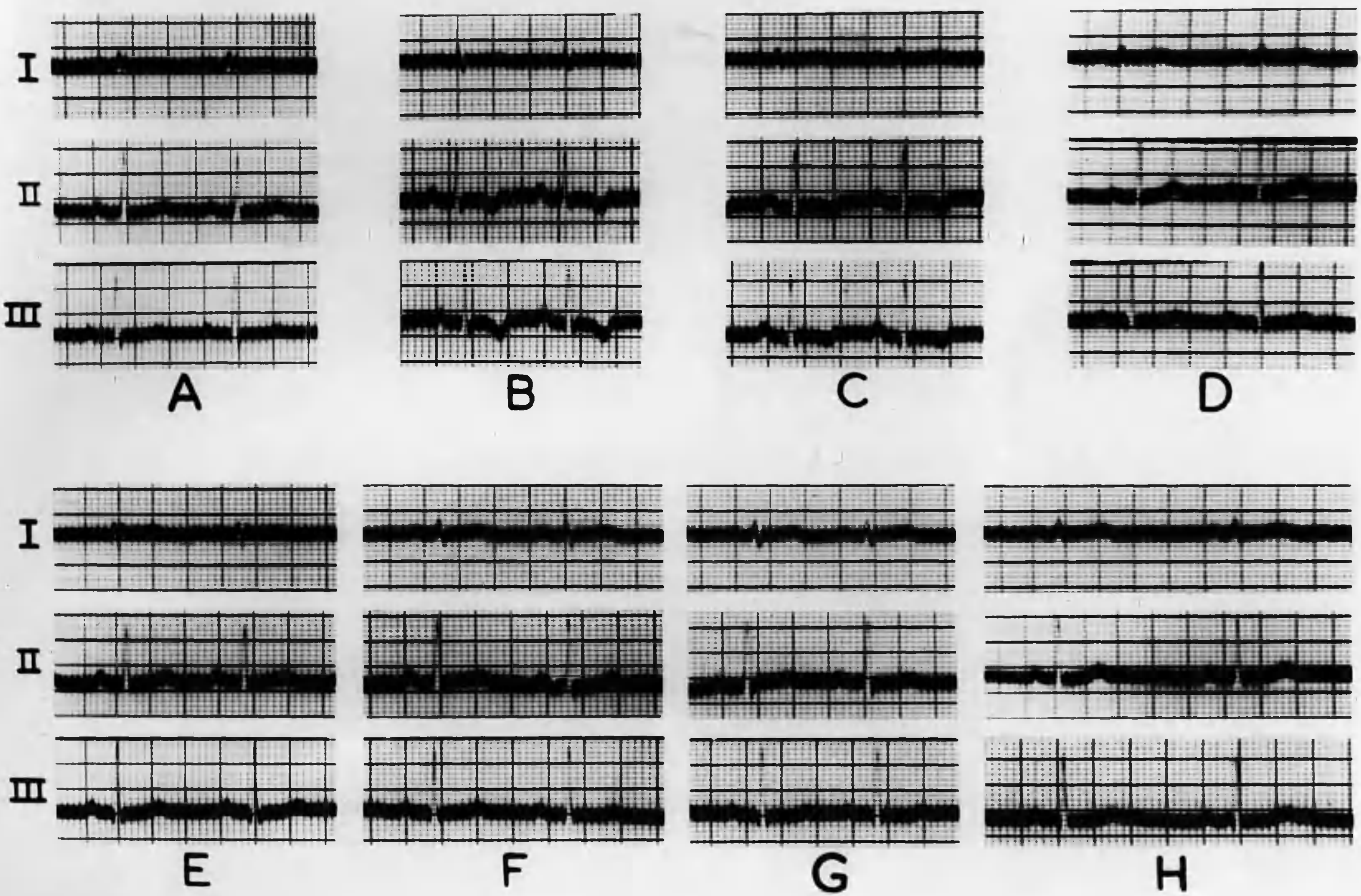
G: Prone.

VI to V3 are similar to the control.

V4 has an Rs pattern. V5 and V6 have qRs patterns.

T is slightly increased in V4 to V6. There has been slight counter-clockwise rotation and forward rotation of apex.

STANDARD LIMB LEADS



NORMAL.

J.H.

Age 28 years.

STANDARD LIMB LEADS

D: Supine.

Lead I has low upright P and T waves and a small Rs pattern.
Lead II has upright P and T waves and an Rs pattern.
Lead III has upright P and T waves and a qRs pattern.
There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I has an Rsr' pattern.
Lead II shows increase in R; T is reduced.
Lead III shows increase in R and s; T is reduced.

B: Standing.

Lead I has a small RS pattern with reduction in R.
Lead II shows increase in P; T is inverted and the ST segment is slightly depressed.
Lead III shows increase in P; T is inverted and the ST segment is slightly depressed.
There has been a shift of the QRS axis to the right.

C: 45° head up.

The changes are similar to those in B but are less marked.

H: 45° head down.

Lead I shows increase in R.
Lead II shows increase in R.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

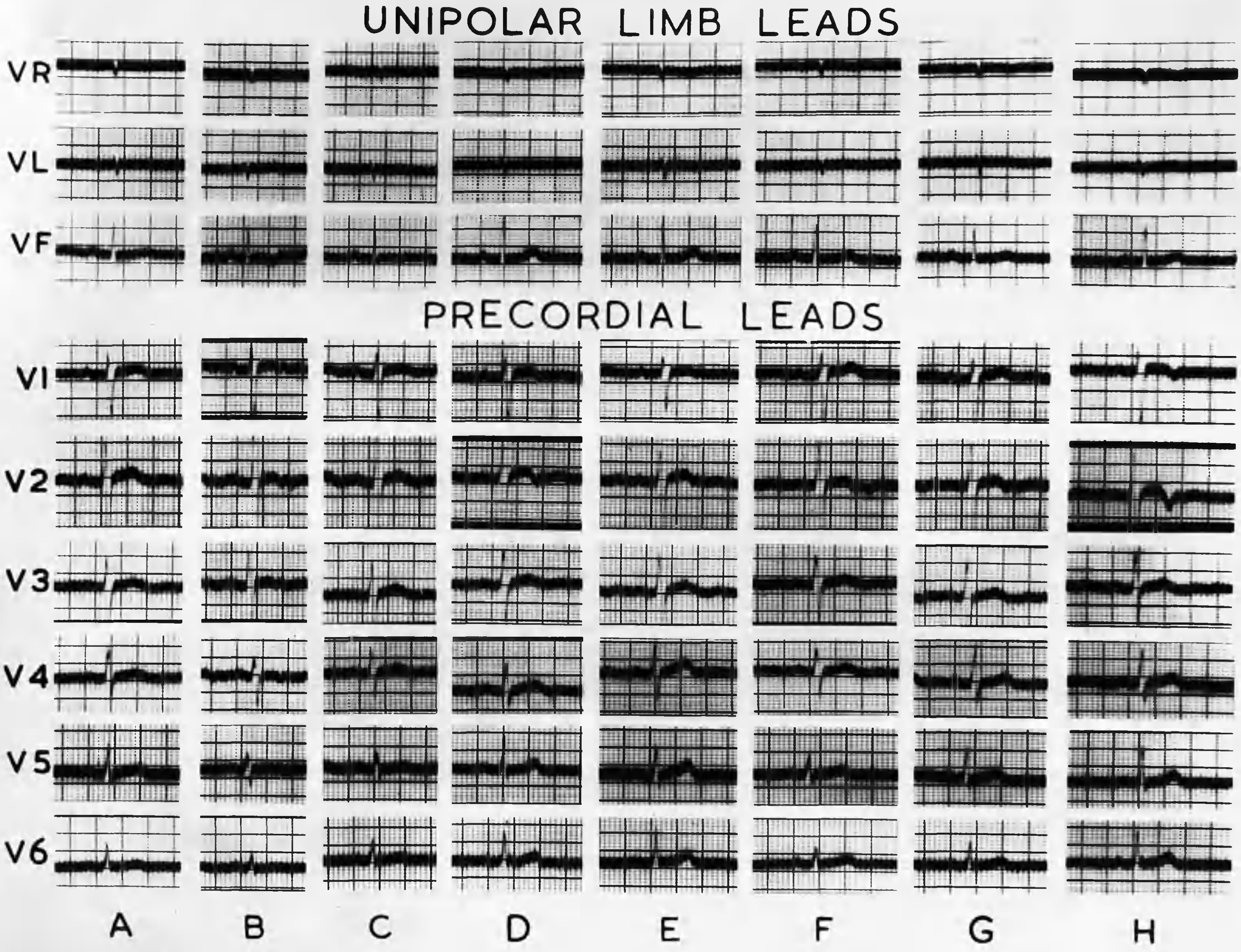
Lead I has an rSr' pattern.
Lead II shows increase in P.
Lead III shows increase in P and R.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I has an RS pattern with increase in S; P is increased.
Lead II shows increase in P and R.
Lead III shows slight increase in R.

G: Prone.

Lead I has an RS pattern with increase in R.
Lead II shows increase in s and decrease in T.
Lead III shows decrease in T.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
VI
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has shallow inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

VL has low upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows less inverted T.
VL shows increase in S; T is increased.
VF shows reduction in R; T is reduced.

B: Standing.

VR has a smaller QS; T is flat.
VL shows increase in S; T is increased.
VF shows increase in P and reduction in R; T is inverted and the ST segment is slightly depressed.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A,B and C the heart has probably become more vertical.

H: 45° head down.

VL has an RS pattern; T is increased.
VF shows reduction in R and T.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VL shows increase in S; T is slightly inverted.
VF has a qR pattern.

F: Right Lateral.

VL has a QS pattern.
VF shows reduction in R and T.

G: Prone.

VL has an rSr' pattern; T is increased.
VF shows reduction in R and T.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have rS patterns; P is upright; T is diphasic but mainly positive.

V3 and V4 have RS patterns; P and T are upright.

V5 and V6 have Rs patterns; P and T are upright.

There is marked clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns.

V4 has an RS pattern with increase in S.

V5 and V6 have Rs patterns with reduction in R.

T is reduced in V4 to V6.

B: Standing.

VI to V4 have rS patterns.

V5 has an RS pattern with reduction in R.

V6 has an Rs pattern with reduction in R.

T is reduced in all leads and is flat in V5 and V6.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A,B and C there has been further clockwise rotation.

H; 45° head down.

The patterns are similar to the control but R is increased in V4 to V6; T is more negative in VI and V2 and is increased in V5 and V6.

The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns.

V4 has an RS pattern.

V5 and V6 have Rs patterns with increase of R in V6.

T is reduced in VI and increased in V4 to V6.

Some displacement to the left has occurred.

F: Right Lateral.

The patterns are similar to the control but r is increased in VI and R is decreased in V5 and V6; T is increased in VI and reduced in V4 to V6.

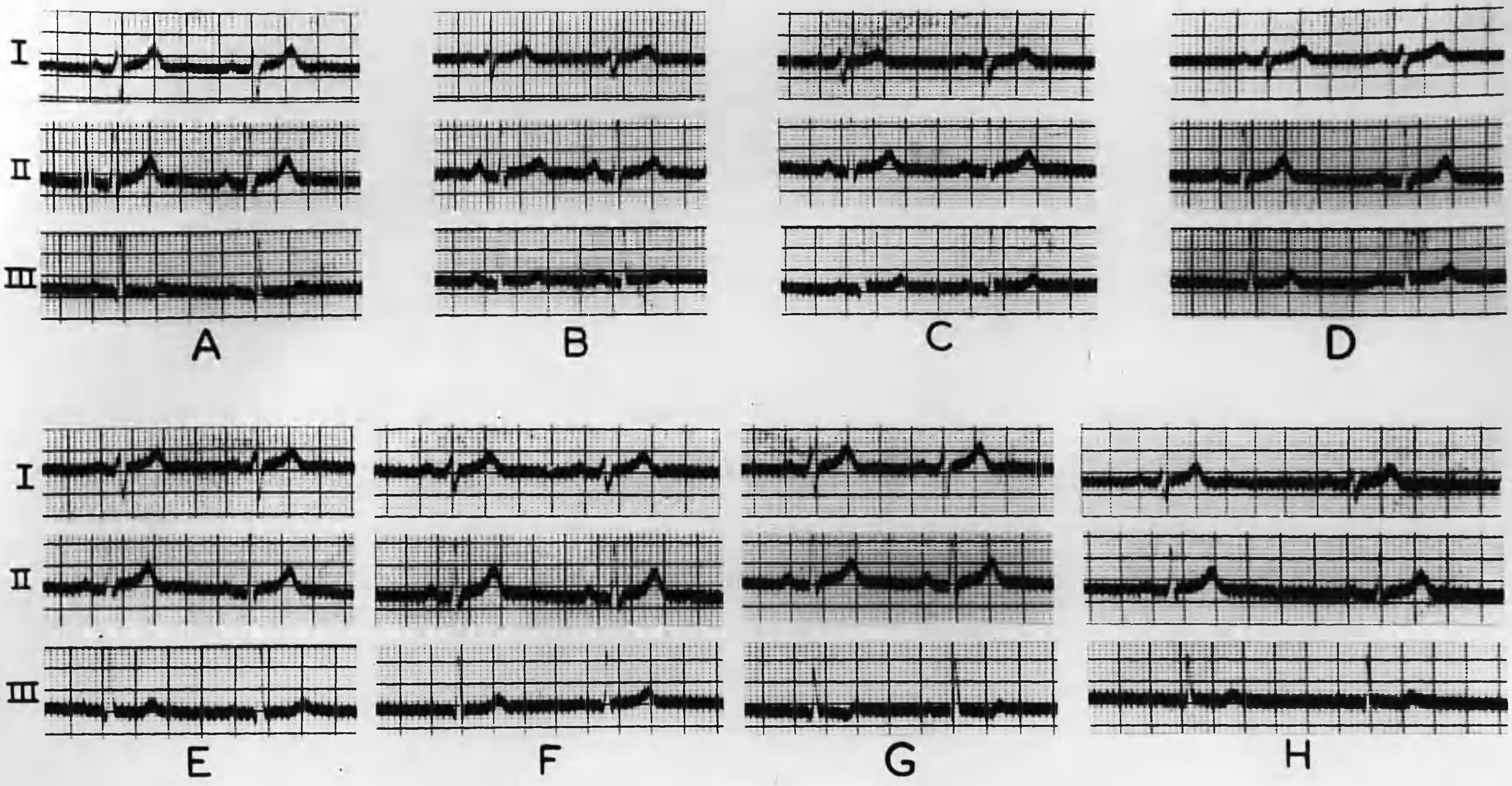
Some displacement to the right has occurred along with backward rotation of the apex.

G: Prone.

The patterns are similar to the control but R is increased in V4; R and T are reduced in V5 and V6.

The heart has probably become more horizontal.

STANDARD LIMB LEADS



NORMAL.

R.B.

Age 28 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an RS pattern.

Leads II and III have upright P and T waves and qRs patterns.

There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I shows increase in R and S; T is increased.
Lead II shows increase in s; P and T are increased.
Lead III shows increase in P; T is reduced.

B: Standing.

Lead I has an rS pattern with increase in S.

Lead II shows increase in s; P is increased and T is reduced.

Lead III shows increase in R and reduction in s; P is increased and T is reduced.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A, B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows reduction in S; T is increased.
Lead II shows reduction in R.
Lead III shows reduction in R; T is reduced.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

Lead I shows increase in S; T is increased.
Lead II shows increase in R.
Lead III has a qR pattern with increase in R; T is slightly reduced.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows increase in R and S; T is increased.
Lead II shows increase in s; T is increased.
Lead III shows increase in s; T is increased.

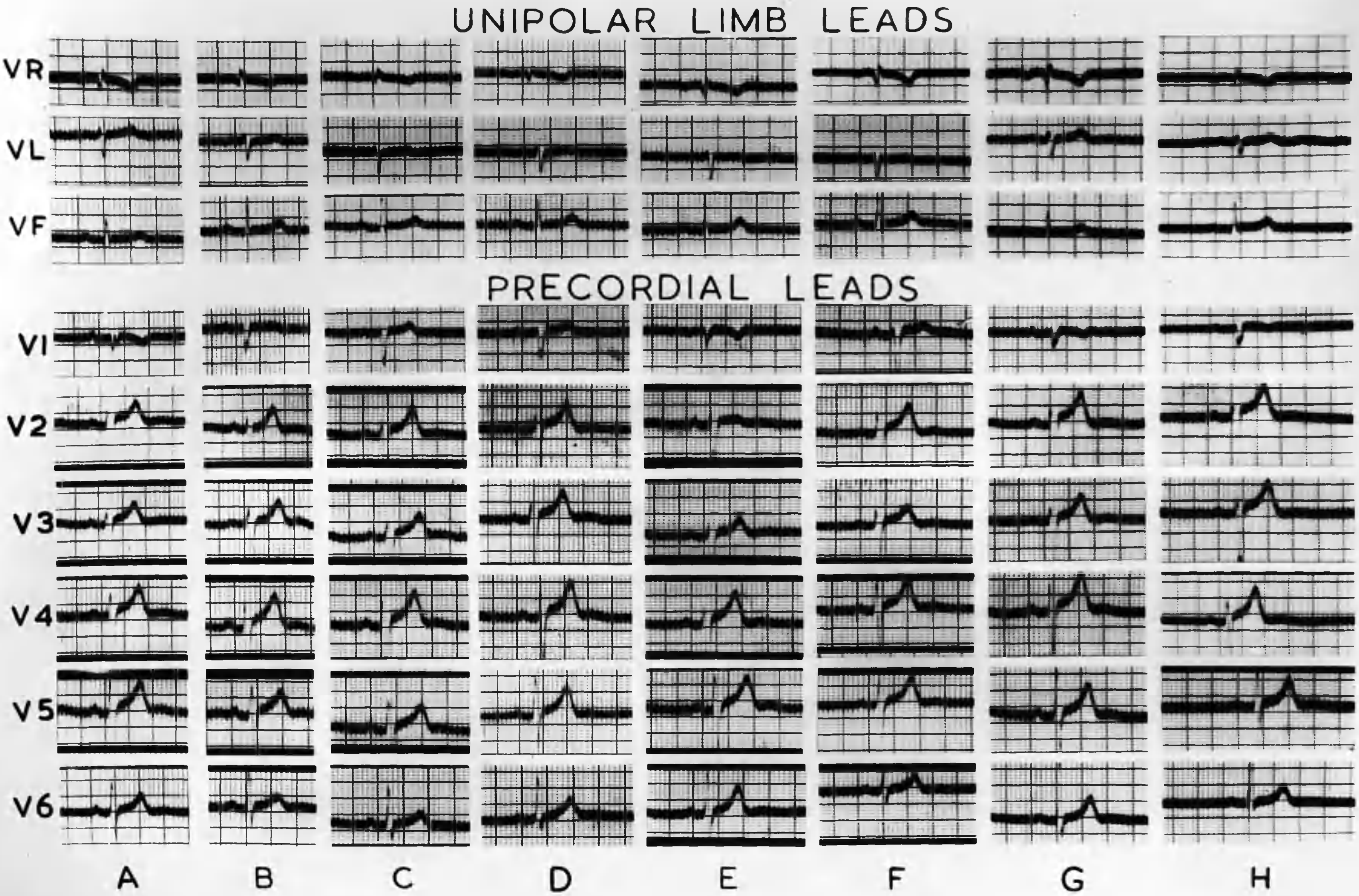
G: Prone.

Lead I shows increase in R and S; T is increased.

Lead II shows reduction in R and increase in s; P and T are increased.

Lead III shows increase in q and reduction in R; T is reduced and is slightly diphasic.

There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
VI
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a QR pattern. It faces the back of the heart.

VL has low upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

VR shows increase in Q and R; T is more inverted.
VL shows increase in S; P is inverted; T is increased.
VF shows reduction in R; T is reduced.

B: Standing.

VL shows increase in S; P is inverted; T is increased.
VF shows increase in R; P is increased; T is reduced.

C: 45° head up.

The changes are similar to those in B.

In B and C the heart has become more vertical.

H: 45° head down.

VR shows more deeply inverted T.
VL shows increase in r and reduction in S; T is increased.
VF shows reduction in R; P and T are reduced.
The heart has become less vertical.

Horizontal Rotation.

E: Left Lateral.

VR shows increase in Q; T is more deeply inverted.
VL shows increase in S.
VF shows increase in R; T is increased.

F: Right Lateral.

VR shows increase in Q; T is more deeply inverted.
VL and VF show no change.

G: Prone.

VR shows increase in Q and R; P and T are more deeply inverted.
VL shows increase in r; P and T are increased.
VF shows reduction in R; P and T are reduced.
The heart has become less vertical.

PRECORDIAL LEADS.

D: Supine.

VI has a QS pattern; P is diphasic and T upright.
V2 to V4 have rS patterns; P and T are upright.
V5 has an RS pattern; P and T are upright.
V6 has an Rs pattern; P and T are upright.
There is marked clockwise rotation.

Vertical Rotation.

A: Sitting.

VI has a splintered QS pattern; T is inverted.
V2 to V5 have rS patterns; T is reduced in V2 to V4.
V6 has an RS pattern.

B: Standing.

VI has a QS pattern; T is reduced.
V2 to V5 have rS patterns; T is reduced.
V6 has an Rs pattern with reduction in R and increase in s; T is reduced.

C: 45° head up.

The patterns are similar to those in B but there is less reduction of T.

In A,B and C there has been further clockwise rotation.

H: 45° head down.

VI has a QS pattern; T is slightly inverted.
V2 to V4 have rS patterns with reduction in S; T is increased in V2 and V3.
V5 has an Rs pattern.
V6 has a qRs pattern.
There has been slight counter-clockwise rotation and the heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI has a splintered QS pattern; P and T are inverted.
V2 to V4 have rS patterns with reduction in r; T is reduced. V5 and V6 have RS patterns; T is increased.
Displacement to the left has occurred.

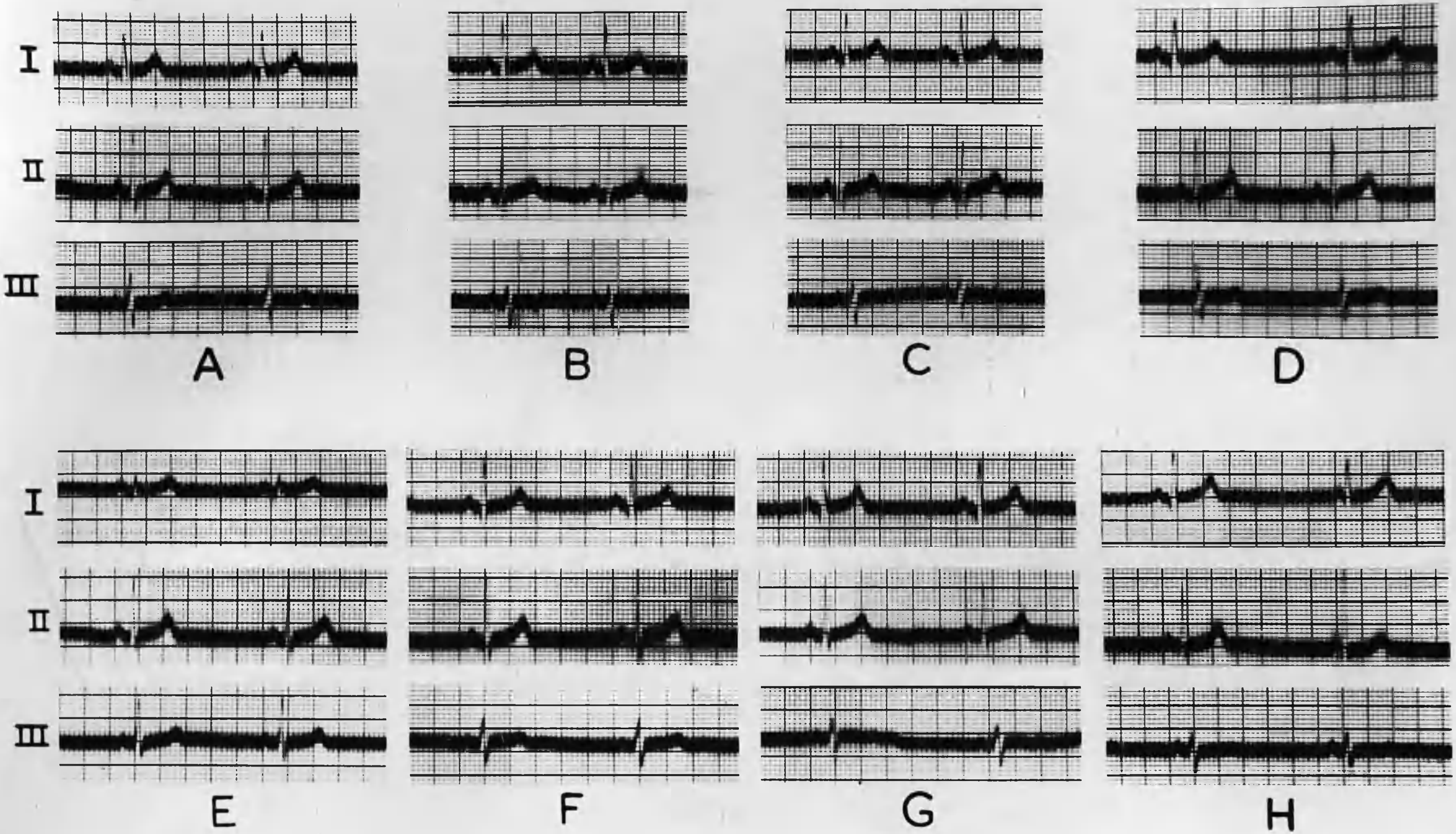
F: Right Lateral.

VI to V4 have rS patterns. V5 has an RS pattern with reduction in R. V6 has an Rs pattern with reduction in R.
T is increased in VI and V2 and reduced in V3 to V6.
Displacement to the right has occurred, with backward rotation of the apex.

G: Prone.

VI to V4 are similar to the control but T is inverted in VI and increased in V4. V5 has an RS pattern with increase in R and T. V6 has a qRs pattern with increase in R and T. The heart has become more horizontal with forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

A.R.

Age I9 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has upright P and T waves and a qR pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has low upright P and T waves and an RS pattern.
There is a tendency to left axis deviation.

Vertical Rotation.

A: Sitting.
Lead I shows reduction in R and increase in T.
Lead II shows increase in R and s; T is reduced.
Lead III shows increase in R; T is reduced.
There has been a shift of the QRS axis to the right.

B: Standing.
Lead II shows reduction in R; P is increased and T is reduced.
Lead III shows reduction in R; P is increased and T is slightly inverted.

C: 45° head up.
The changes are similar to those in B.

H: 45° head down.
Lead I shows increase in R and T.
Lead II shows increase in R.
Lead III shows reduction in R and T.
Leads I and II show nodal escape.
There has been a shift of the QRS axis to the left.

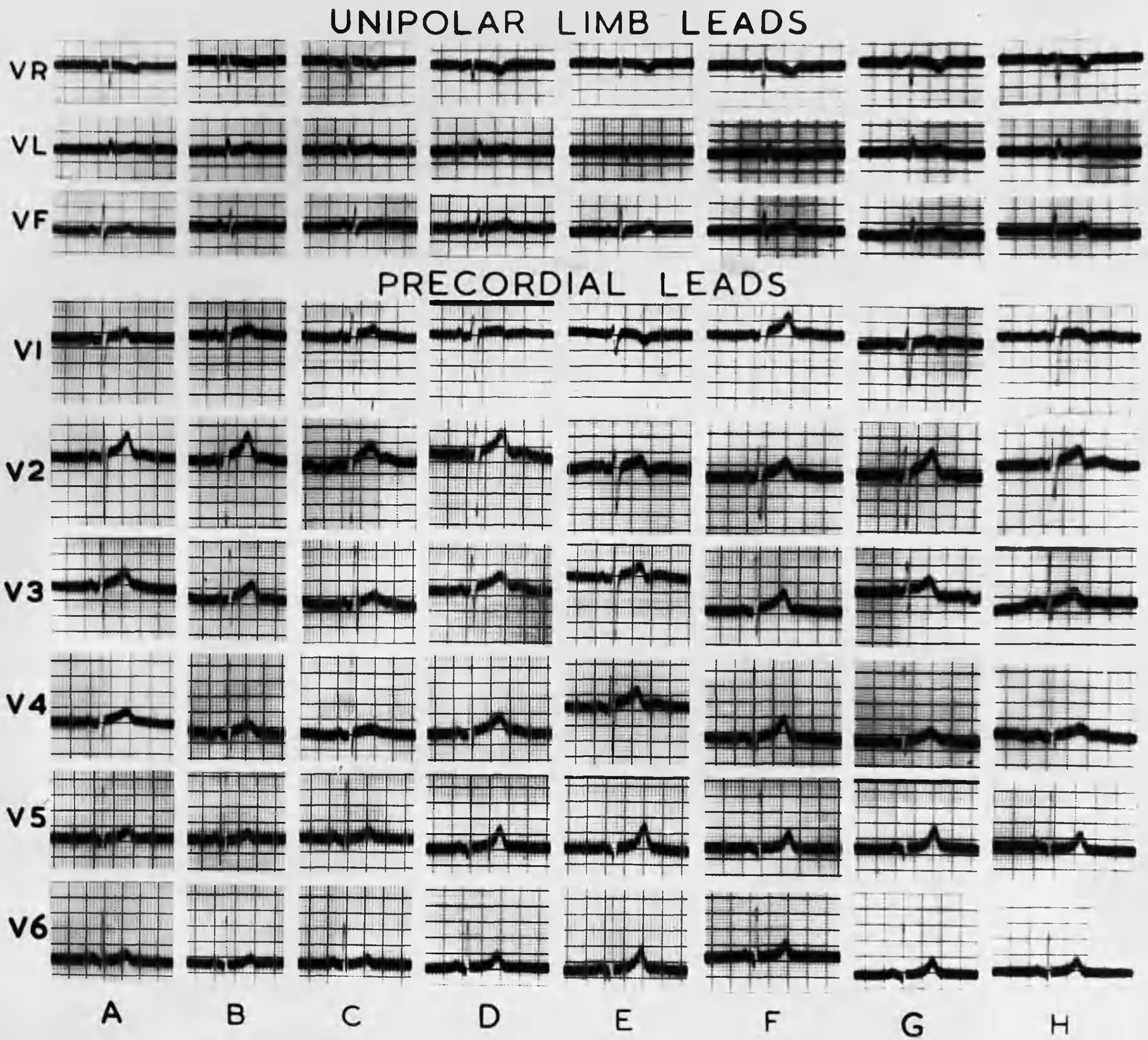
Horizontal Rotation.

E: Left Lateral.
Lead I has a small splintered R pattern; T is reduced.
Lead II shows increase in R and reduction in q.
Lead III has an Rs pattern with increase in R; T is increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.
Lead I has a qRs pattern with increase in R.
Lead II shows increase in R and s.
Lead III shows increase in R and S.
There has been a shift of the QRS axis to the left.

G: Prone.

Lead I shows increase in R and T.
Lead II shows decrease in R.
Lead III shows decrease in R and increase in S; T is flat.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.
VR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.
VL has low upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.
VF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.
The heart is horizontal.

Vertical Rotation.
A: Sitting.
VR shows increase in S; T is less inverted.
VL shows reduction in R.
VF shows increase in R and s; T is reduced.
The heart has become less horizontal.

B: Standing.
VR shows increase in S; T is less inverted.
VF shows increase in R and s; T is flat.

C: 45° head up.
The changes are similar to those in B.

H: 45° head down.
VR shows increase in S; T is more inverted.
VL shows increase in R and T.
VF shows increase in R and reduction in s; T is increased.
The heart has become more horizontal.

Horizontal Rotation.
E: Left Lateral.
VL has an rSr' pattern; T is reduced.
VF shows increase in R; T is increased.
There has probably been some forward rotation of the apex.

F: Right Lateral.
VR shows increase in S.
VL has flat T.
VF shows increase in R and s.

G: Prone.
VR shows increase in S.
VL shows increase in R and T.
VF shows reduction in P and T.
The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have rS patterns; P and T are upright.
V3 has an RS pattern; P and T are upright.
V4 to V6 have qRs patterns; P and T are upright.
There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 are similar to the control.

V4 has an Rs pattern with increase in s; T is reduced.

V5 and V6 have qRs patterns with reduction in R and increase in s; T is reduced in both.

There has been slight clockwise rotation and the heart has become more vertical.

B: Standing.

The patterns are similar to those in A but T is further reduced in V4 to V6.

C: 45° head up.

The patterns are similar to those in B.

H: 45° head down.

VI has an rS pattern.
V2 has an RS pattern, with reduction in S.
V3 has an Rs pattern.
V4 to V6 have qRs patterns.
There has been some counter-clockwise rotation.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns with reduction of r and S in VI and V2 and increase of S in V3; T is inverted in VI.

V4 has an RS pattern.

V5 and V6 have qRs patterns with increase in q and R; T is increased.

Displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

VI has an rS pattern with increase in r and S; T is increased.

V2 has an RS pattern.

V3 to V6 have qRs patterns; T is reduced in V5 and V6.

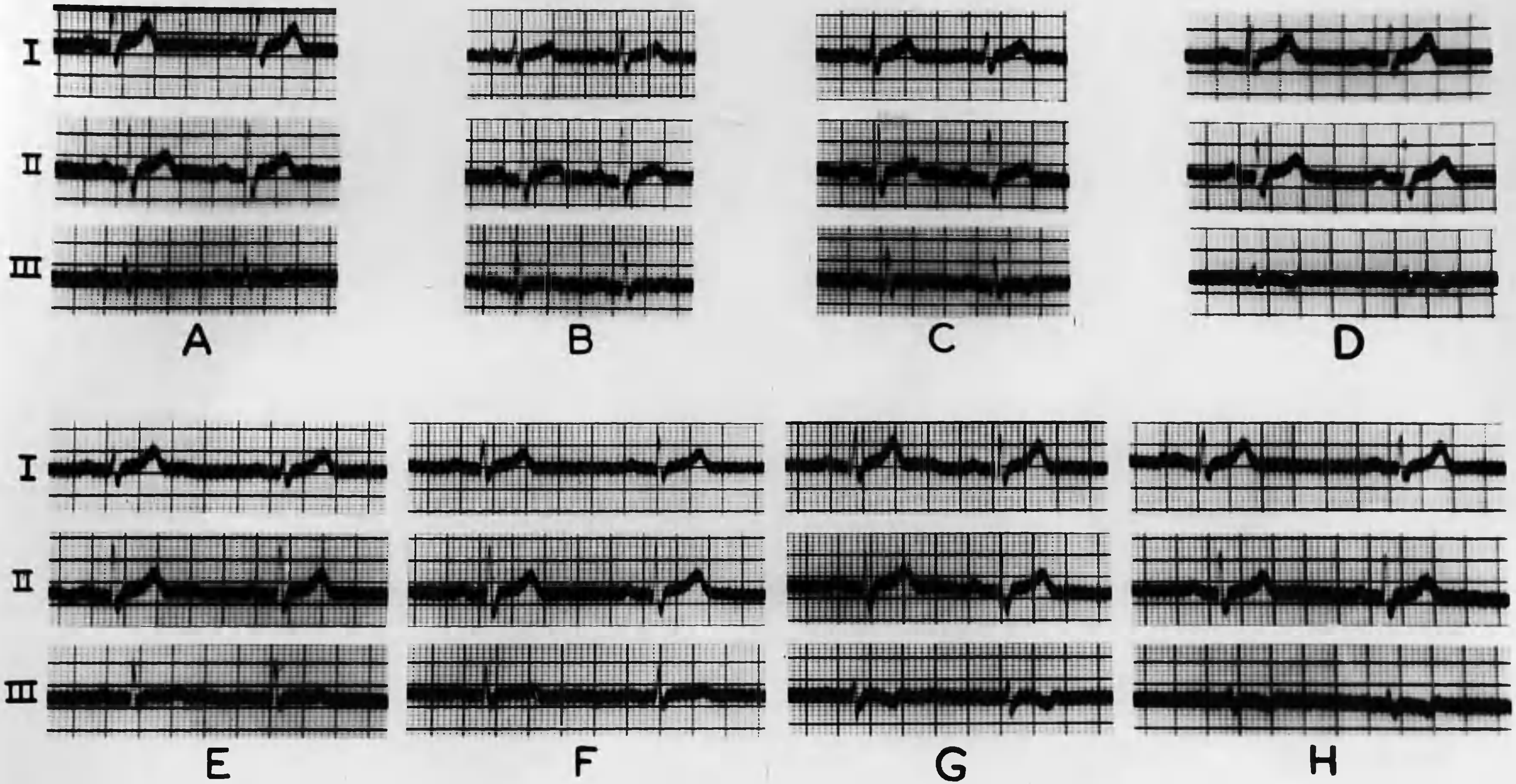
Displacement to the right has occurred.

G: Prone.

The patterns are similar to the control but in VI T is diphasic; in V5 and V6 q,R and T are increased.

The heart has become slightly more horizontal and there has been some forward rotation of the apex.

STANDARD LIMB LEADS



CASE NO. 20 PLATE I50a

NORMAL. R.W.

Age 27 years.

STANDARD LIMB LEADS.

D: Supine.

Leads I and II have upright P and T waves and qRs patterns.

Lead III has low upright P and diphasic but mainly negative T waves and an Rs pattern.

Vertical Rotation.

A: Sitting.

Lead I shows increase in s.
Lead II shows increase in R and s.
Lead III shows increase in R; T is less negative.

B: Standing.

Lead I shows reduction in R and increase in s; T is reduced.

Lead II shows increase in R and s; T is reduced.

Lead III has a qRs pattern with increase in R; T is less negative.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A, B and C there has been a shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in q and reduction in s; T is increased.

Lead II shows increase in s.
Lead III has an RS pattern; T is more negative.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

Lead I shows reduction in R.

Lead II shows increase in R and reduction in s; T is increased.

Lead III has a qRs pattern with increase in R; T is upright.

There has been a shift of the QRS axis to the right.

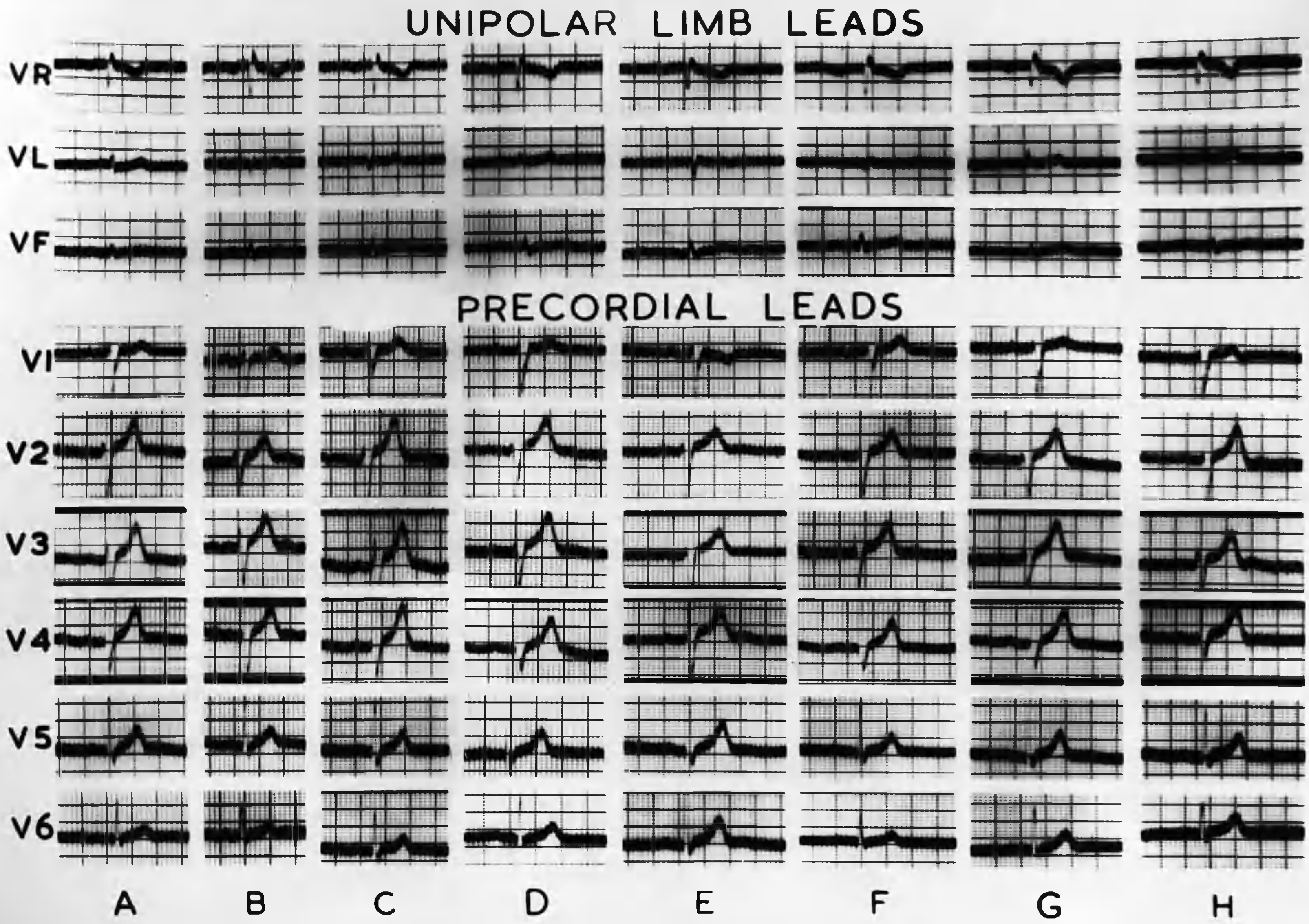
F: Right Lateral.

Lead I shows reduction in R and s; T is reduced.
Lead II shows increase in R.
Lead III has a qRs pattern with increase in R and s;

F; Lead III (contd.)
T is upright.

G: Prone.

Lead I shows increase in R and T.
Lead II shows reduction in R and increase in s.
Lead III has an RS pattern; T is more inverted.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
VI
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has upright P and T waves and a small vibratory qrsr' pattern. It faces the epicardial surface of the left ventricle.

VF has upright P and T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal.

Vertical Rotation.

A: Sitting.

VR shows increase in r.
VL has a splintered Rs pattern.
VF has an Rs pattern with reduction in R.

B: Standing.

VR has an rSr' pattern.
VL has a splintered qr pattern; T is reduced.
VF shows reduction in S.

C: 45° head up.

VR has an rSr' pattern.
VL has an rS pattern.
VF shows reduction in S.

H: 45° head down.

VR shows more deeply inverted T.
VL shows increase in T.
VF shows reduction in R.
The heart has probably become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VL has an rSr' pattern; T is flat.
VF shows increase in R and T.

F: Right Lateral.

VR shows increase in Q and r.
VL has a qr pattern; T is flat.
VF shows increase in R and T.

G: Prone.

VR shows increase in r; T is more inverted.
VL has an R pattern; T is increased.
VF shows reduction in R.
The heart has probably become more horizontal.

The direction of T in lead III depends on the value of T in VL Thus in E and F it is upright due to the flat T in VL; in G and H it is more inverted due to the increased T in VL.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns; P and T are upright.
V4 to V6 have qRs patterns; P and T are upright.
There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control but s is increased in V4 and V5; T is reduced in V6.

B: Standing.

The patterns are similar to the control but s is increased in V4 to V6; R is reduced in V5 and V6; T is reduced in V2 to V6.

There has been slight clockwise rotation.

C: 45° head up.

The patterns are similar to the control but s is increased in V4 to V6 and R is reduced in V5 and V6.

H: 45° head down.

The patterns are similar to the control but R is reduced in V5 and V6.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns with increase in q, R and s.

T is inverted in VI, reduced in V2 and V3 and increased in V5 and V6.

Some displacement to the left has occurred with forward rotation of the apex.

F: Right Lateral.

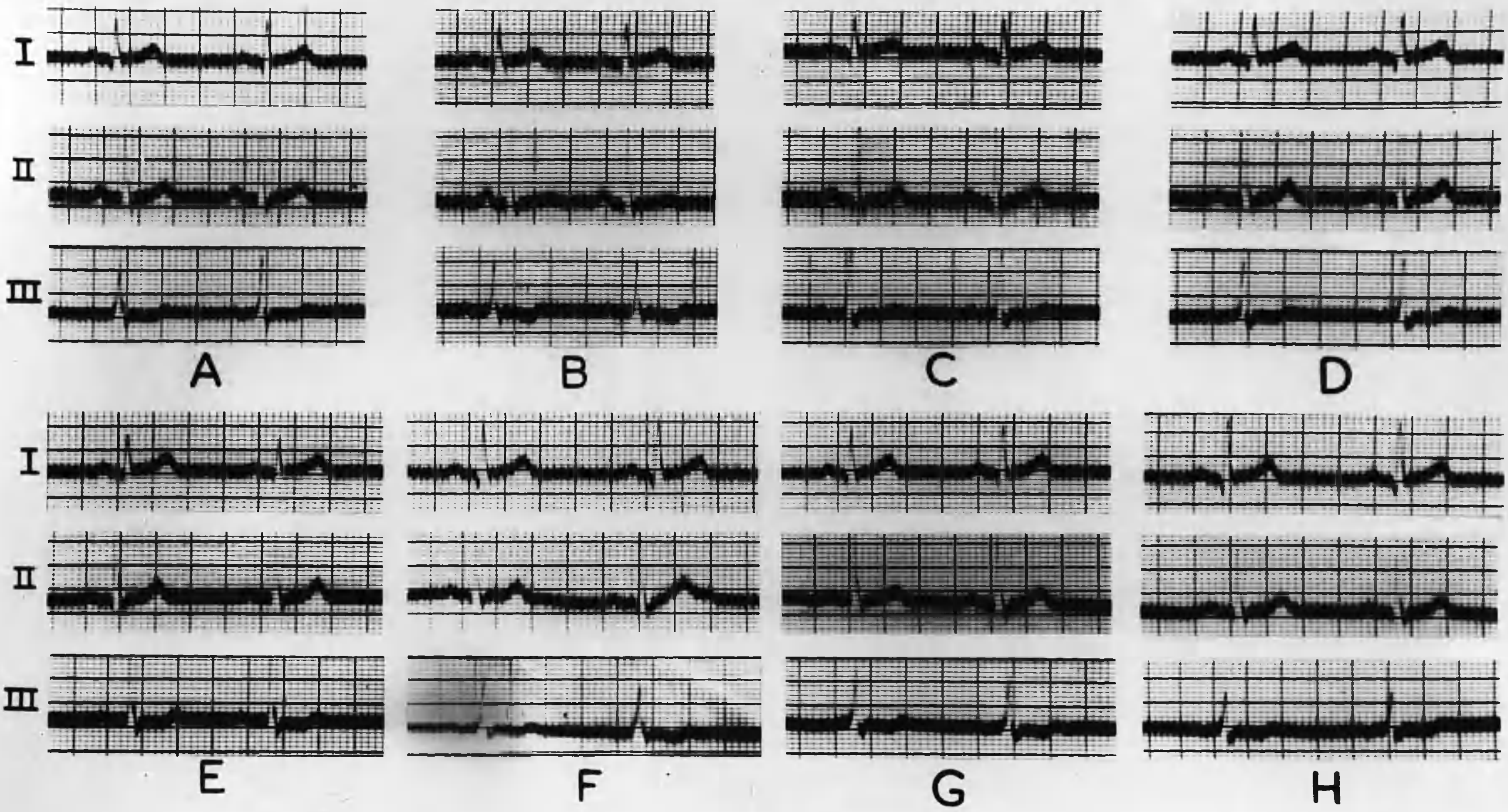
The patterns are similar to the control but R is reduced in V5 and V6; T is increased in VI and reduced in all other leads.

Displacement to the right has occurred with backward rotation of the apex.

G: Prone.

The patterns are similar to the control.

STANDARD LIMB LEADS



CASE NO. 21 PLATE I5Ia

NORMAL. B.A.

Age I9 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and a qR pattern.
Lead II has upright P and T waves and a qRs pattern.
Lead III has diphasic P and T waves and an Rs pattern.

Vertical Rotation.

A: Sitting.

Lead I shows reduction in q and R.
Lead II shows reduction in q; P is increased; T is reduced.
Lead III shows increase in R and s; P is more positive; T is diphasic but less positive.

B: Standing.

Lead I shows reduction in q and R; T is reduced.
Lead II shows reduction in q; P is increased; T is reduced.
Lead III shows reduction in R; P is more positive; T is inverted.

C: 45° head up.

Lead I shows reduction in q and R; T is reduced.
Lead II shows increase in P; T is reduced.
Lead III shows increase in R; P is more positive; T is less positive.

In A, B and C there has been a slight shift of the QRS axis to the right.

H: 45° head down.

Lead I shows increase in q and R; T is increased.
Lead III shows reduction in R; T is more negative.
There has been a shift of the QRS axis to the left.

Horizontal Rotation.

E: Left Lateral.

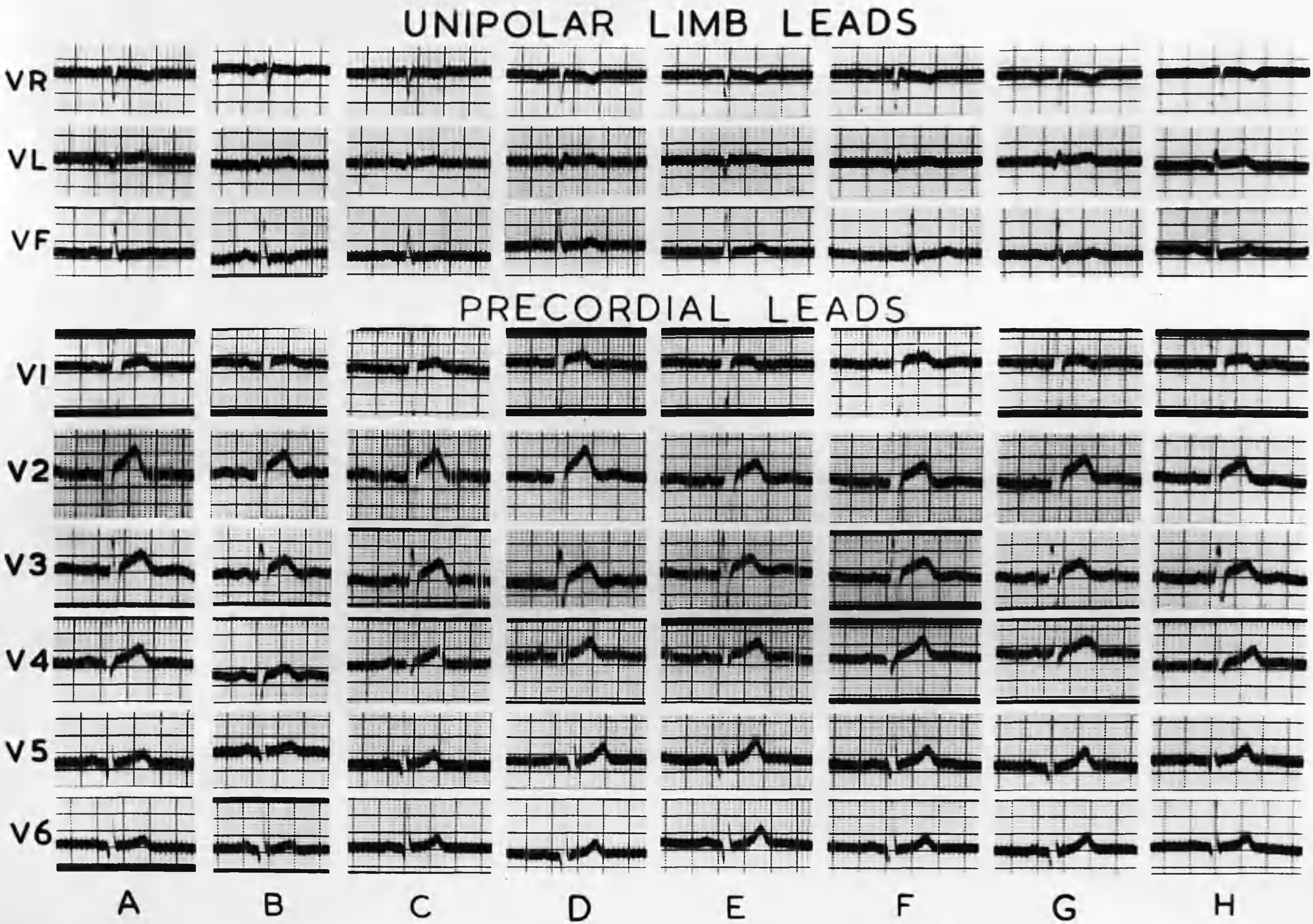
Lead I shows reduction in q and R; T is increased.
Lead III shows a qRs pattern with increase in R; P is more positive;T is still diphasic but of increased amplitude.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows increase in q and R; T is increased.
Lead II shows increase in s.
Lead III shows reduction in R; T is still diphasic but of increased amplitude.
There has been a shift of the QRS axis to the left.

G: Prone.

Lead I shows increase in R; T is increased.
Lead II shows increase in s.
Lead III shows decrease in R; T is more negative.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
VI
V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

VL has upright P and T waves and a qr pattern. It faces the epicardial surface of the left ventricle.

VF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is horizontal with forward rotation of the apex.

Vertical Rotation.

A: Sitting.

VR shows less inverted T.
VL shows reduction in r.
VF shows reduction in q and R; P is increased; T is reduced.

The heart has become less horizontal and there has been backward rotation of the apex.

B: Standing.

VR shows less inverted T.
VL shows reduction in r; P is inverted.
VF shows increase in R; P is increased; T is inverted.

C: 45° head up.

VR shows less inverted T.
VL shows reduction in r.
VF shows reduction in R; P is increased; T is reduced.

In B and C the heart has become less horizontal.

H: 45° head down.

VR has an rS pattern. It faces the cavity of the right ventricle. VL has a qR pattern; T is increased. VF shows increase in P; T is reduced.

The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in S. VL has a Qr pattern; T is reduced. There has been forward rotation of the apex.

F: Right Lateral.

VR shows increase in r,S and r'. VL shows increase in q; T is reduced. VF shows increase in R and s.

G: Prone.

VR shows more deeply inverted T. VL has a qR pattern; T is increased. VF shows reduction in R and increase in s; T is reduced.

The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI has an rS pattern; P and T are upright.
V2 and V3 have RS patterns; P and T are upright.
V4 to V6 have qRs patterns; P and T are upright.
There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns.
V4 to V6 have qRs patterns with increase of s in V4.
T is reduced in VI, V5 and V6.
There has been slight clockwise rotation.

B: Standing.

VI to V3 have rS patterns.
V4 to V6 have qRs patterns with increase of s in V4 and reduction of q in V4 to V6.
T is reduced in all leads.
There has been clockwise rotation.

C: 45° head up.

The changes are similar to those in B but are less marked.

H: 45° head down.

The patterns are similar to the control but q is reduced in V4 to V6; T is reduced in VI to V3.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI has an rS pattern with reduction in S.
V2 and V3 have RS patterns with increase of R and S in V3.
V4 to V6 have qRs patterns with increase in q and R.
T is reduced in VI to V3 and increased in V5 and V6.
Displacement to the left has occurred with forward rotation of the apex.

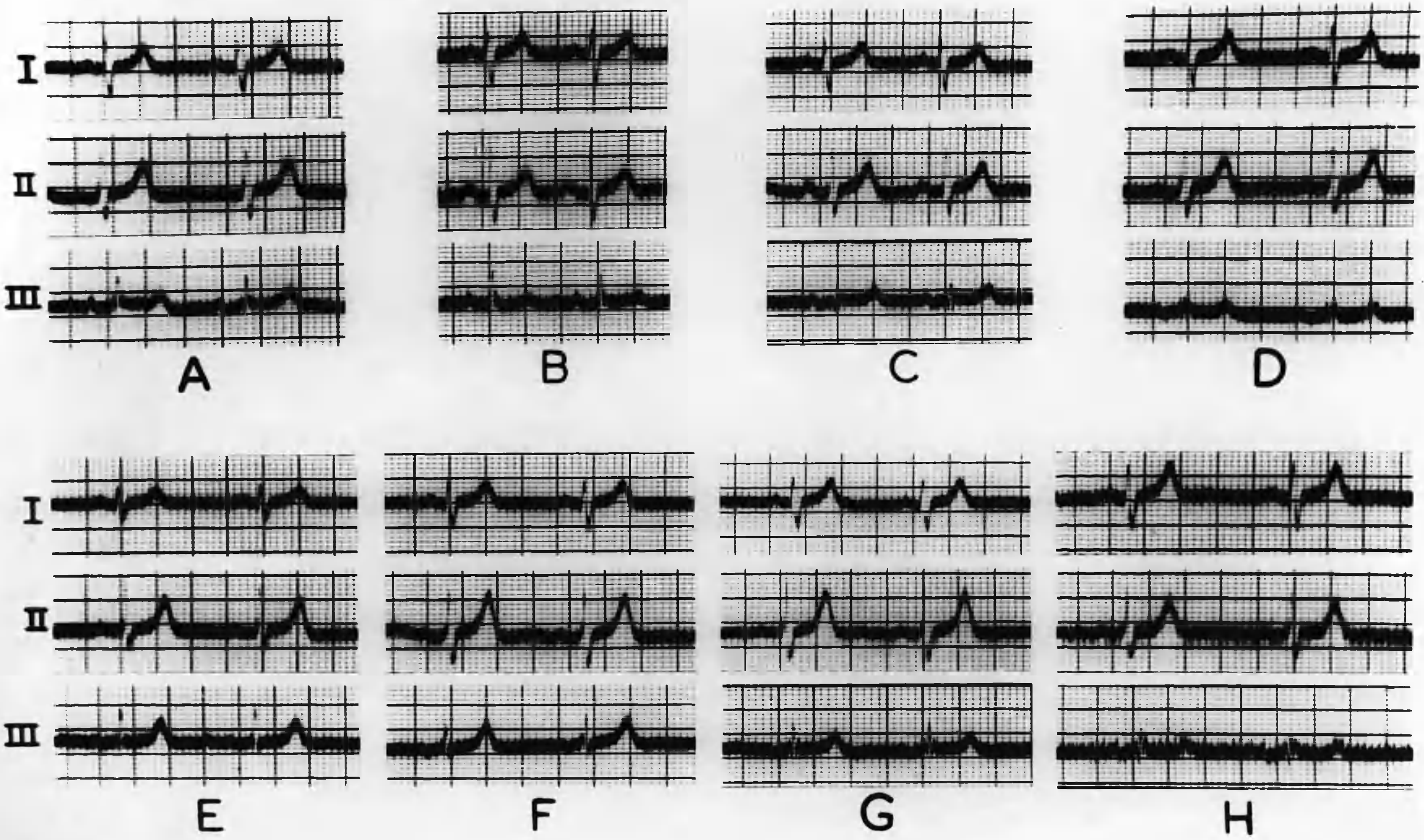
F: Right Lateral.

The patterns are similar to the control but r is increased in VI; R and T are reduced in V6.
Some displacement to the right has occurred.

G: Prone.

The patterns are similar to the control but T is reduced in VI to V3 and increased in V5 and V6.
The heart has probably become more horizontal and there has been slight forward rotation of the apex.

STANDARD LIMB LEADS



CASE NO.22

NORMAL.

A.R.

Age 22 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has a qRS pattern; P and T are upright.
Lead II has an Rs pattern; P and T are upright.
Lead III have a small vibratory rsr's'r'' pattern; P is diphasic and T is upright.

Vertical Rotation.

A: Sitting.

Lead I shows decrease in R.
Lead II shows increase in R.
Lead III has a splintered R pattern.
There has been a shift of the QRS axis to the right.

B: Standing.

Lead I shows decrease in R; T is reduced.
Lead II shows increase in R and s; P is increased and T is reduced.
Lead III has a splintered R pattern; P is increased and T is reduced.
There has been a shift of the QRS axis to the right.

C: 45^{o} head up.

Lead I shows decrease in R; T is reduced.
Lead II shows increase in R; P is increased and T is reduced.
Lead III has an rsR's'r' pattern; P is increased.
There has been a shift of the QRS axis to the right.

H: 45^{o} head down.

Lead I shows increase in R; T is increased.
Lead III has an rSR's'r' pattern.

Horizontal Rotation.

E: Left Lateral.

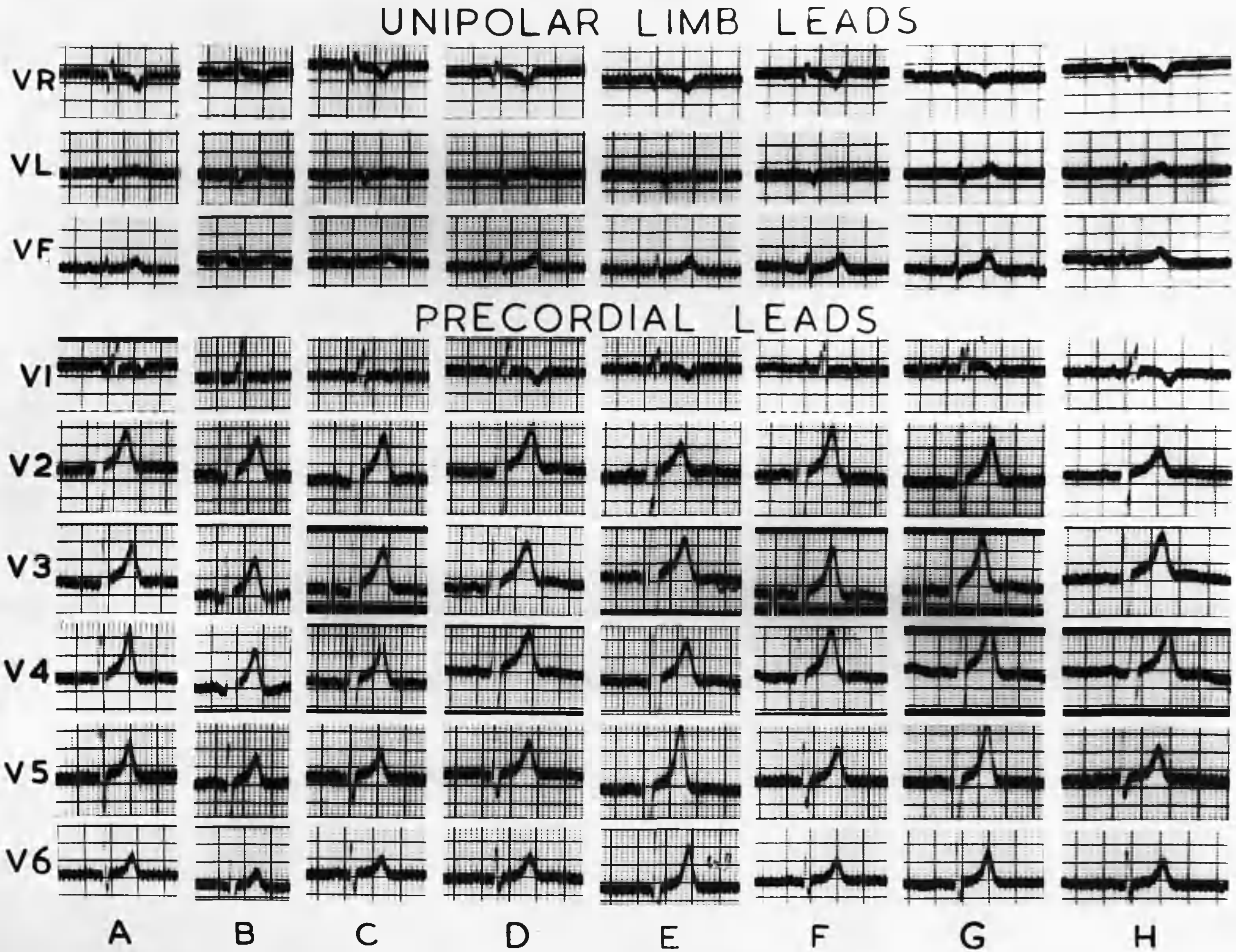
Lead I shows reduction in R and S; T is reduced.
Lead II shows increase in R and reduction in s.
Lead III has an rsR's'r'' pattern; T is increased.
There has been a shift of the QRS axis to the right.

F: Right Lateral.

Lead I shows slight reduction in R and S; T is reduced.
Lead II shows increase in R; T is increased.
Lead III has a splintered Rs pattern; T is increased.
There has been a shift of the QRS axis to the right.

G: Prone.

Lead I shows reduction in R and S.
Lead II shows increase in R; T is increased.
Lead III has an rsR's'r'' pattern; T is increased.


UNIPOLAR LIMB LEADS
PRECORDIAL LEADS
VR
VL
VF
VI
V2
V3
V4
V5
V6
A
B
C
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E
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G
H

UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a QR pattern. It faces the back of the heart.

VL has upright P and T waves and a qRS pattern. It faces the epicardial surface of the left ventricle.

VF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal.

Vertical Rotation.

A: Sitting.

VR shows increase in Q and R; T is more inverted.
VL has a qRS pattern with increase in S.
VF shows reduction in s; T is reduced.

B: Standing.

VR shows less inverted T.

VL has an RS pattern. It now faces the epicardial surface of the right ventricle.

VF has a qR pattern; P is increased and T is reduced. It now faces the epicardial surface of the left ventricle.

The heart has become vertical.

C: 45° head up.

The changes are similar to those in B but are less marked.

H: 45° head down.

VR has an rSr' pattern. It faces the epicardial surface of the right ventricle.

VL shows increase in q and R; T is increased.
VF has a splintered Rs pattern.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in Q and R; T is less inverted.
VL shows reduction in R and S; T is flat.
VF shows increase in R and T.

F: Right Lateral.

VL has a qrS pattern; T is reduced.
VF has an RS pattern; T is increased.

G: Prone.

VR has an rSR' pattern; T is less inverted.
VL has a qRS pattern with increase in R; T is increased.
VF has an RS pattern.
The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI has an rsR's' pattern; P is upright and T is inverted.

V2 to V4 have RS patterns; P and T are upright.

V5 and V6 have qRs patterns; P and T are upright.

There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control but s is increased in V5 and V6.

B: Standing.

VI is similar to the control but T is diphasic.

V2 to V4 show reduction in R and T.

V5 has a qRS pattern; T is reduced.

V6 has a qRs pattern with reduction in R and increase in s; T is reduced.

There has been further clockwise rotation and the heart has become more vertical.

C: 45° head up.

The patterns are similar to those in B.

H: 45° head down.

The patterns are similar to the control.

Horizontal Rotation.

E: Left Lateral.

VI to V4 are similar to the control but r and R' are reduced in VI and T is less inverted; T is reduced in V2.

V5 has a qRS pattern with increase in R; T is increased.

V6 has a qRs pattern with increase in q,R and s; T is increased.

Some displacement to the left has occurred along with forward rotation of the apex.

F: Right Lateral.

The patterns are similar to the control but r is increased and T is less inverted in VI; T is increased in V2 to V4; R and T are reduced and s is increased in V5 and V6.

Some displacement to the right has occurred with backward rotation of the apex.

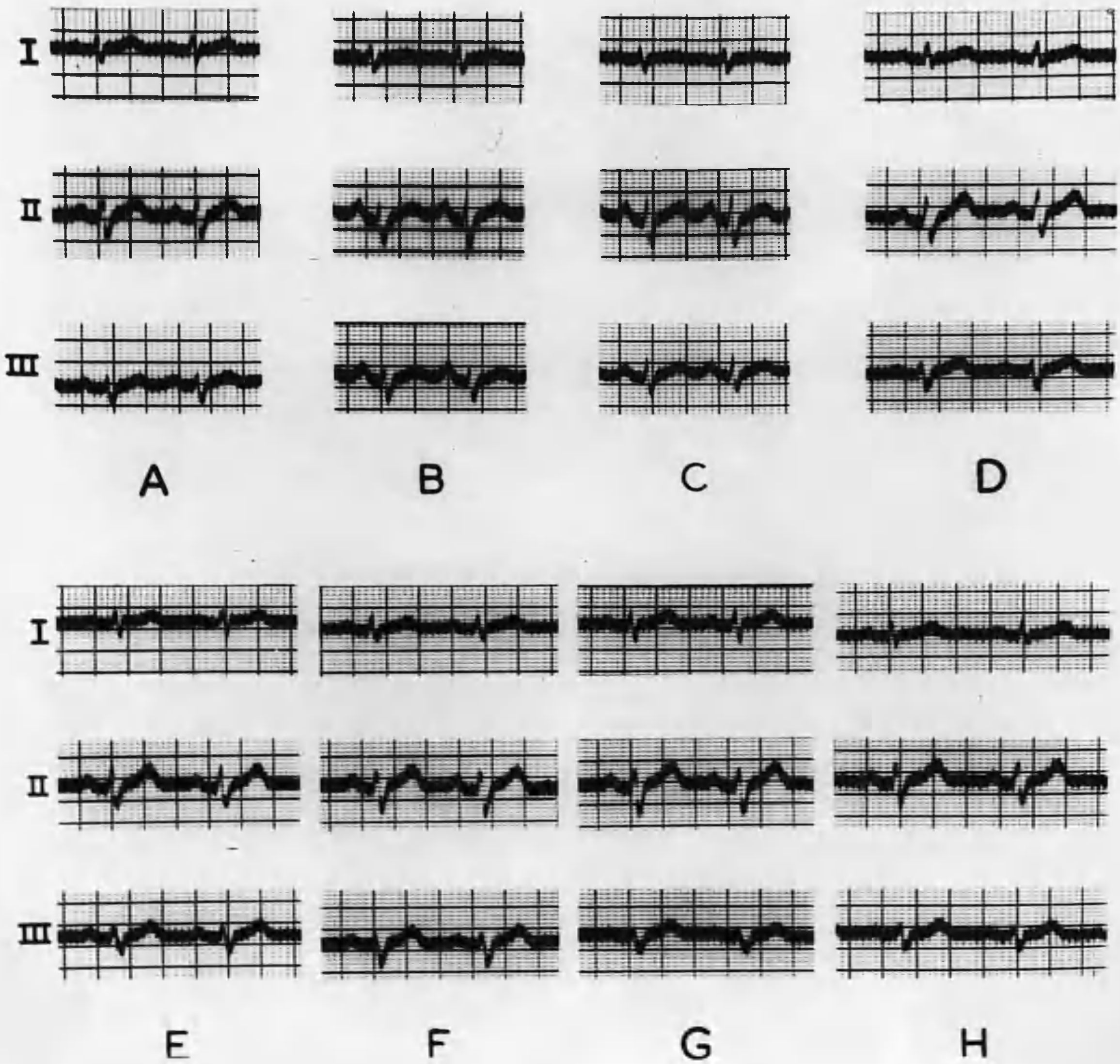
G: Prone.

VI to V3 are similar to the control.

V4 to V6 show changes similar to those in E.

There has been some forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL.

W.B.

Age 32 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has upright P and T waves and an Rs pattern.
Lead II has upright P and T waves and an RS pattern.
Lead III has upright P and T waves and an rS pattern.
There is a tendency to left axis deviation.

Vertical Rotation.
A: Sitting.
Lead I has an RS pattern with reduction in R.
Lead II has an RS pattern with reduction in R; T is reduced.
Lead III shows reduction in r; T is reduced.

B: Standing.
Lead I has an RS pattern with reduction in R; T is reduced.
Lead II has an RS pattern with reduction in R and increase in S; P is increased; T is reduced.
Lead III shows increase in r and S; P is increased; T is reduced.

C: 45^{o} head up.
The changes are similar to those in B.

In A,B and C there has been a shift of the QRS axis to the right.

H: 45^{o} head down.
Lead I shows increase in T.
Lead II shows reduction in R; T is increased.
Lead III shows reduction in r; T is increased.

Horizontal Rotation.
E: Left Lateral.
Lead I has an RS pattern with reduction in R.
Lead II shows reduction in S.
Lead III shows increase in r and reduction in S; T is increased.
There has been a shift of the QRS axis to the right.

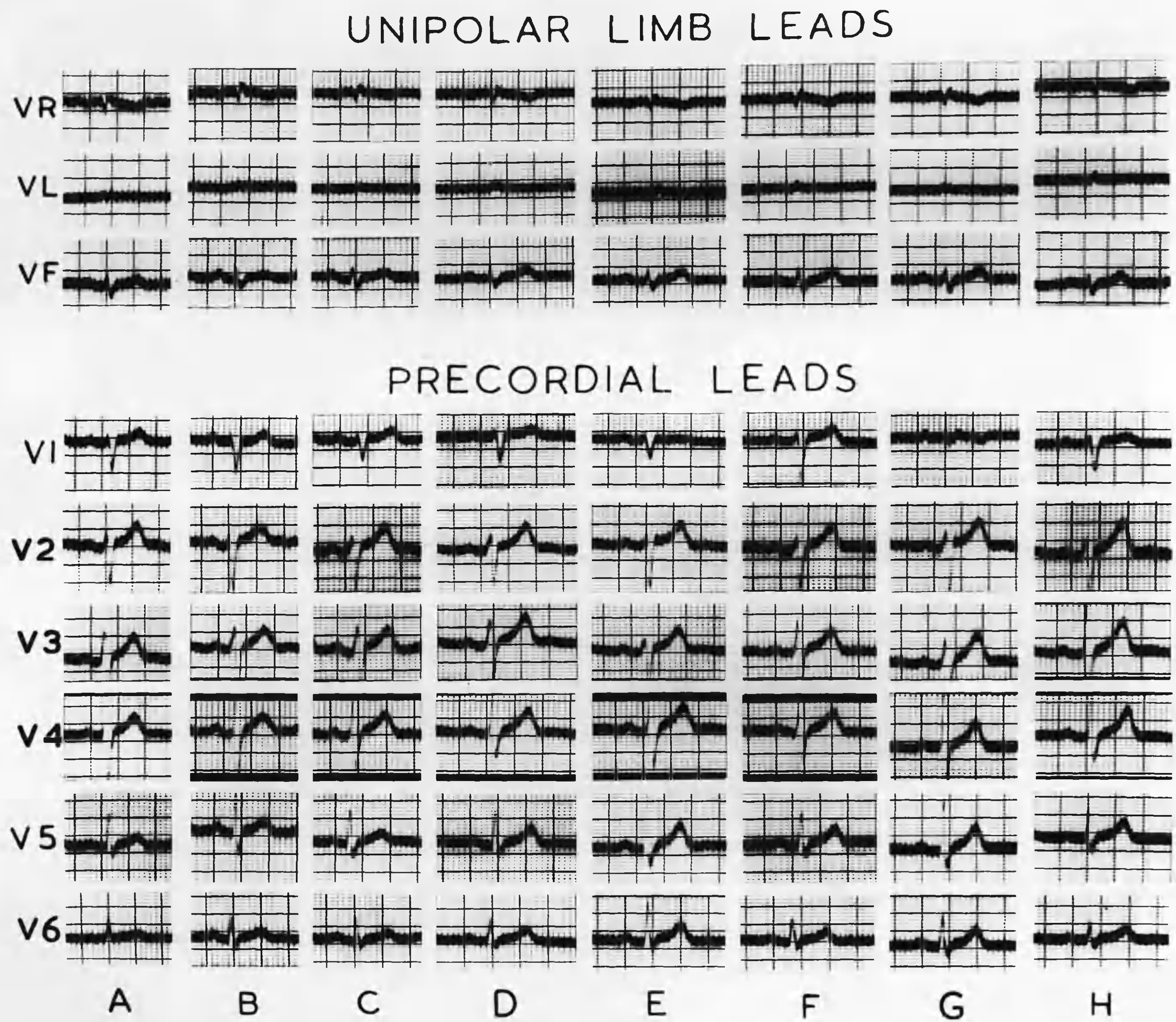
F: Right Lateral.
Lead I shows reduction in R and increase in s; T is increased.
Lead II shows reduction in R and increase in S; T is increased.
Lead III shows increase in S; T is increased.
There has been a shift of the QRS axis to the left.

G: Prone.

Lead I has an RS pattern with increase in R; T is increased.

Lead II shows reduction in R and increase in S; T is increased.

Lead III shows reduction in r and S.


UNIPOLAR LIMB LEADS
VR
VL
VF
PRECORDIAL LEADS
VI
V2
V3
V4
V5
V6
A
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UNIPOLAR LIMB LEADS.

D: Supine.

VR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

VL has flat P and T waves and a small qr pattern. It tends to face the epicardial surface of the left ventricle.

VF has upright P and T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control.

B: Standing.

VR shows increase in r; T is less inverted.
VL has slightly inverted P.
VF shows increase in P; T is reduced.

C: 45° head up.

The changes are similar to those in B.

H: 45° head down.

VR shows reduction in Q and R.
VL shows increase in R.
VF shows increase in S; T is increased.
The heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VR shows reduction in Q.
VL shows slight inversion of T.
VF shows increase in T.

F: Right Lateral.

VR shows increase in R.
VL shows slight inversion of T.
VF shows increase in R and S; T is increased.

G: Prone.

VL shows slight inversion of T.
VF shows increase in R and S; T is increased.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns; P and T are upright.
V4 has an Rs pattern; P and T are upright.
V5 and V6 have qRs patterns; P and T are upright.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns with decrease of R in V6: T is reduced in V5 and V6.

B: Standing.

VI to V3 have rS patterns with reduction in r.
V4 has an RS pattern.
V5 and V6 have qRs patterns with increase in s.
T is increased in VI and reduced in all other leads.
P is increased in all leads.

C: 45° head up.

The patterns are similar to those in B.

In A,B and C there has been some clockwise rotation.

H: 45° head down.

VI and V2 have rS patterns.
V3 has an RS pattern.
V4 has an Rs pattern.
V5 and V6 have qRs patterns with reduction in q and R. T is reduced in VI and increased in V2 to V4.

There has been slight counter-clockwise rotation and the heart has become more horizontal.

Horizontal Rotation.

E: Left Lateral.

VI to V3 have rS patterns with reduction of r and S in VI and of r in V2 and V3. V4 has an RS pattern. V5 and V6 have qRs patterns with increase in R and s.

T is reduced in VI to V3 and increased in V4 to V6.

Displacement to the left has occurred with forward rotation of the apex.

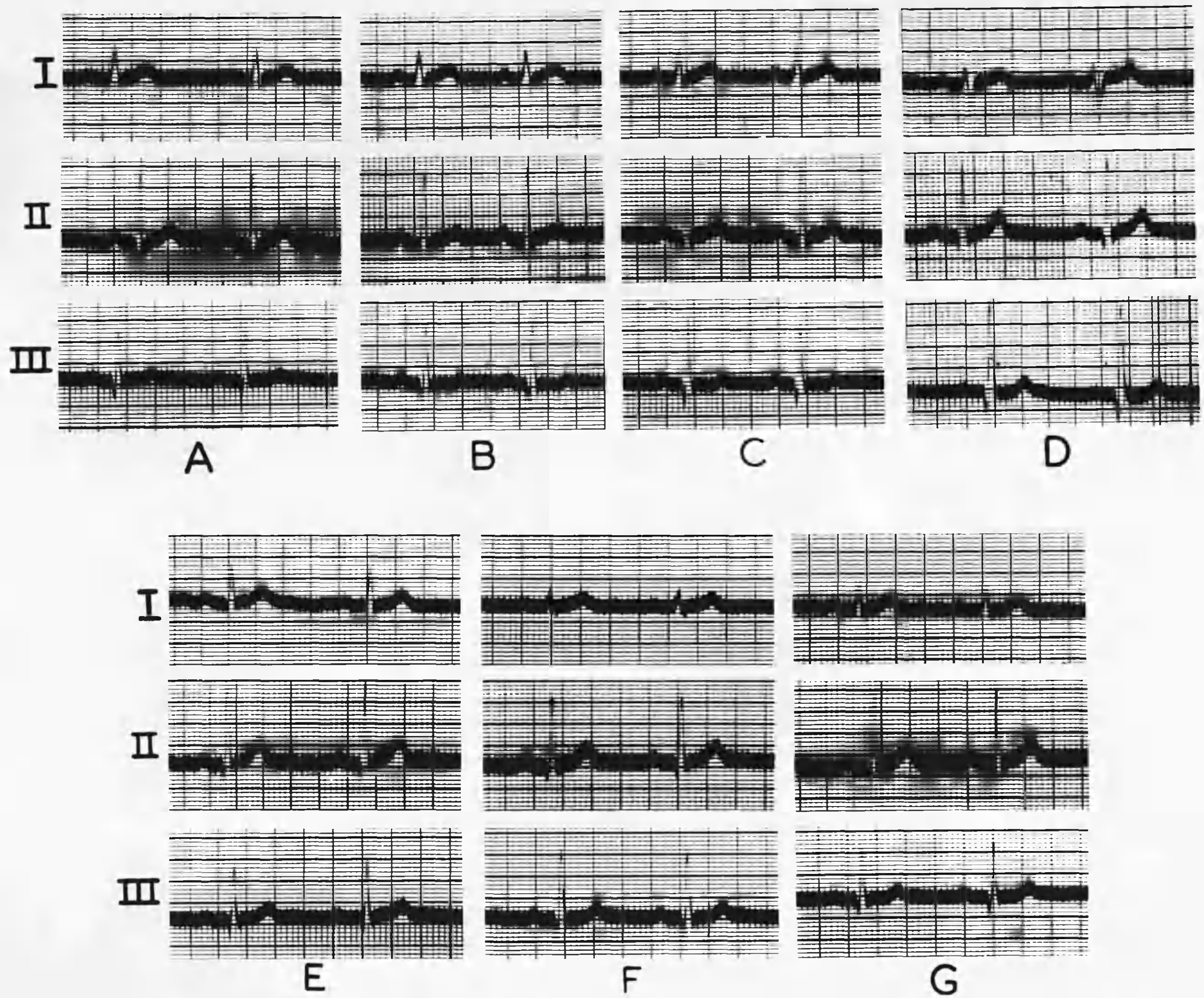
F: Right Lateral.

The patterns are similar to the control but r and S are increased in VI. T is increased in VI and reduced in all other leads. Some displacement to the right has occurred.

G: Prone.

VI has a small splintered rs with inverted T. V4 to V6 are similar to E due to forward rotation of apex.

STANDARD LIMB LEADS



NORMAL.

P.H.

Age 29 years.

STANDARD LIMB LEADS

D: Supine.
Lead I has an rS pattern.
Lead II has a qRs pattern.
Lead III has a qR pattern.
P and T are upright in all leads.
There is right axis deviation.

Vertical Rotation.
A: Sitting.
Lead I has an Rs pattern.
Lead II shows reduction in T.
Lead III has a qRs pattern with reduction in q and R; T is reduced.
There has been a shift of the QRS axis to the left.

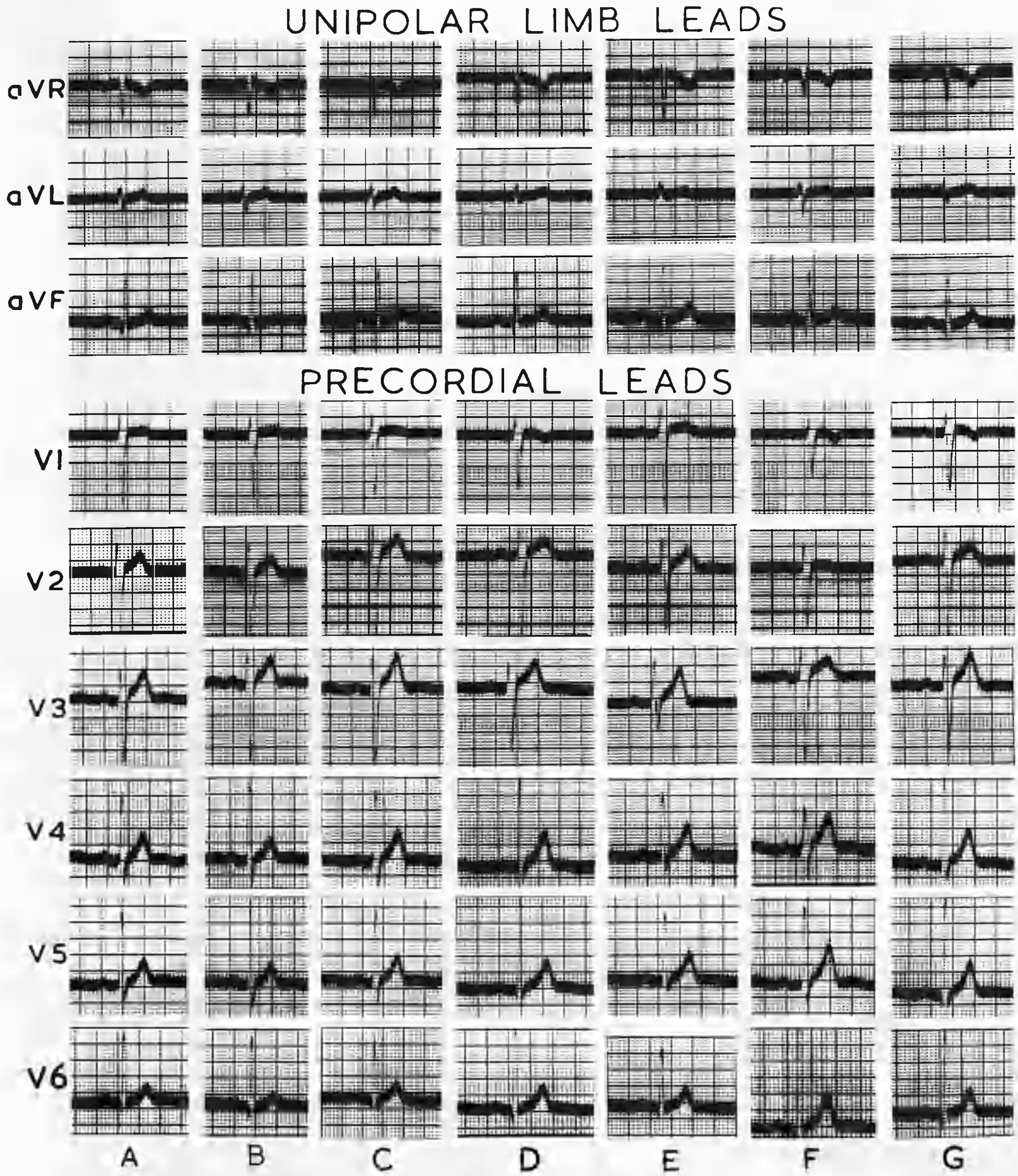
B: Standing.
Lead I has an Rs pattern.
Lead II shows reduction in T.
Lead III has a qRs pattern with reduction in q and R; T is diphasic, and the ST interval is slightly depressed.
There has been a shift of the QRS axis to the left.

C: 45° head up.
The changes are similar to those in B but are of less degree.

Horizontal Rotation.
E: Right Lateral.
Lead I shows a qRs pattern; T is increased.
Lead II shows increase in R and T.
Lead III has a qRs pattern with reduction in q and R.
There has been a shift of the QRS axis to the left.

F: Left Lateral.
Lead I has a small Rs pattern.
Lead II shows reduction in R and T.
Lead III has a qRs pattern with reduction in q and R.
There has been only a slight shift of the QRS axis to the left.

G: Prone.
Lead I has an Rs pattern.
Lead III has a qRs pattern with decrease in q and R; T is decreased.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
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D
E
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UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It probably faces the cavity of the right ventricle.

aVL has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

aVR has a Qr pattern; T is less inverted. It tends to face the back of the heart.

aVL has an RS pattern; T is increased.

aVF shows reduction in T.

The heart has become more vertical.

B: Standing.

aVR has a Qr pattern; T is less inverted.

aVL has an rS pattern; P is flat and T is increased.

aVF has a qRs pattern with increase in q and R; T is reduced and the ST segment is slightly depressed.

The heart has become more vertical and there has been clockwise rotation.

C: 45^{o} head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

aVR has an rS pattern; T is more deeply inverted. It faces the cavity of the right ventricle.

aVL has a splintered R pattern; T is reduced. It faces the epicardial surface of the right ventricle.

aVF has a qRs pattern with increase in R; T is increased. It faces the epicardial surface of the left ventricle.

The heart has probably become less vertical.

F: Left Lateral.

aVR has a Qr pattern; T is less inverted. It faces the back of the heart.

aVL has an rS pattern; P is flat and T is reduced.

aVF shows reduction in T.

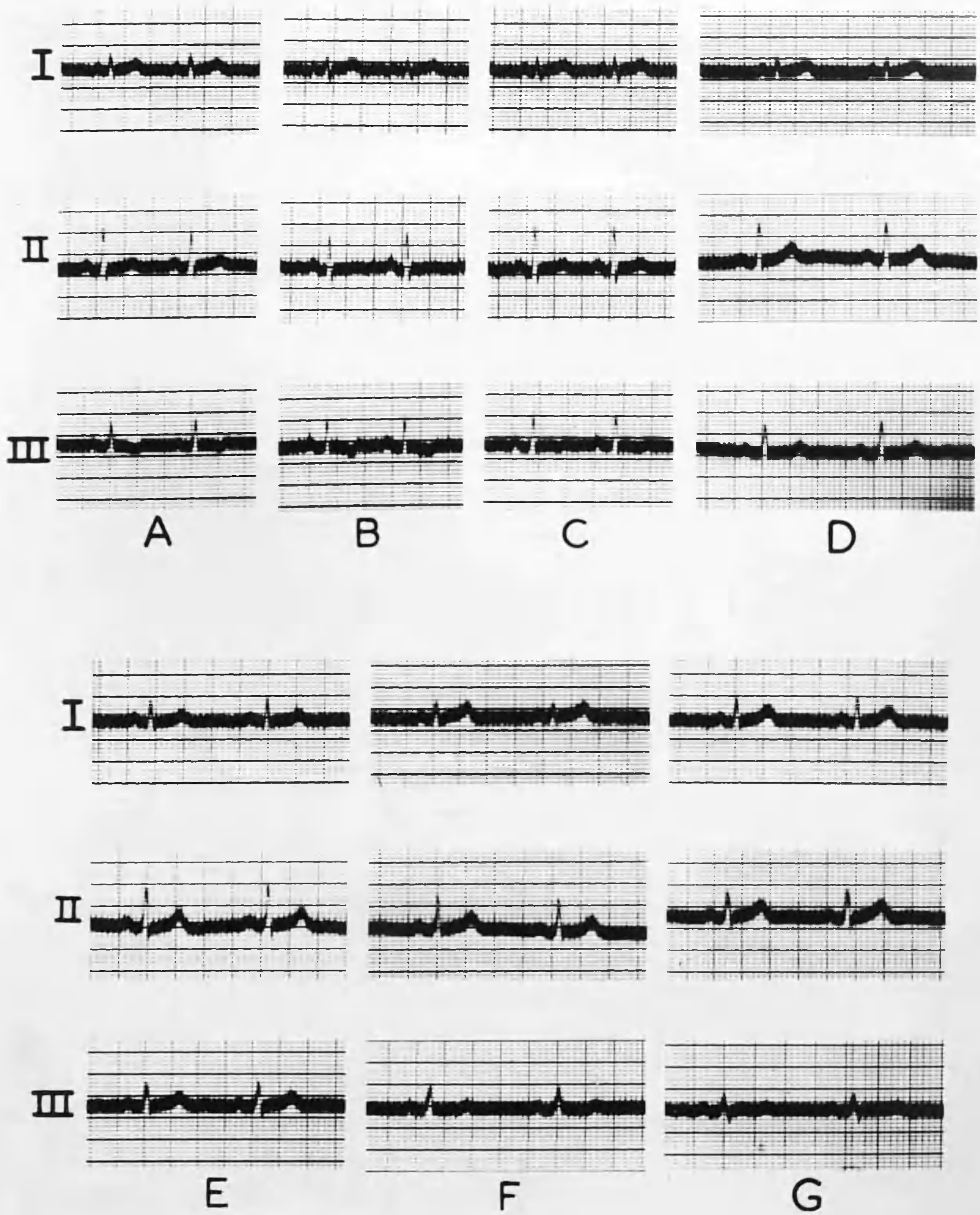
There has been forward rotation of the apex.

G: Prone.

aVL has an RS pattern.

There has been some forward rotation of the apex.

STANDARD LIMB LEADS



CASE NO.35 PLATE I55a

NORMAL. G.McL.

Age 32 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has a qRs pattern.
Leads II and III have Rs patterns.
All leads have upright P and T waves.
There is a tendency to right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I shows decrease in R.
Lead II shows decrease in T.
Lead III shows decrease in R; T is inverted.

B: Standing.

Lead I has an RS pattern; T is reduced.
Lead II shows decrease in R and increase in s; P is increased; T is flat.
Lead III shows increase in P; T is inverted.
There has been a shift of the QRS axis to the right.

C: 45^{o} head up.

Lead I has an RS pattern; T is reduced.
Lead II shows increase in P,R and s; T is reduced.
Lead III shows increase in P and R; T is diphasic.
There has been a shift of the QRS axis to the right.

Horizontal Rotation.

E: Right Lateral.

Lead I shows increase in R.
Lead II shows increase in s and T.
Lead III shows decrease in R and increase in s; T is increased.
There has been a shift of the QRS axis to the left.

F: Left Lateral.

Lead I shows increase in T.
Lead II shows decrease in R.
Lead III shows an R pattern of decreased amplitude; T is reduced.

G: Prone.

Lead I shows increase in R and T.
Lead II shows decrease in R and increase in s; T is increased.
Lead III shows an RS pattern with decrease in R; T is reduced.
There has been a shift of the QRS axis to the left.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.

V4 to V6 have qRs patterns.

P is upright in all leads; T is slightly inverted in VI and upright in all other leads.

There is moderate counter-clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns with increase in S.

V4 and V5 have Rs patterns.

V6 has a qRs pattern with reduction in q and R.

T is low upright in VI and reduced in V4 to V6.

There has been clockwise rotation.

B: Standing.

VI to V3 have rS patterns with increase in S.

V4 and V5 have Rs patterns.

V6 has a qRs pattern with reduction in q and R and increase in s.

T is low upright in VI and reduced in V4 to V6.

There has been clockwise rotation.

C: 45° head up.

The patterns are similar to those in B.

Horizontal Rotation.

E: Right Lateral.

VI and V2 have rS patterns with increase in S in VI and decrease of S in V2.

V3 and V4 have Rs patterns.

V5 and V6 have qRs patterns with decrease in q and R.

T is increased in VI to V3 and decreased in V6.

Some displacement to the right has occurred along with backward rotation of the apex.

F: Left Lateral.

VI and V2 have rS patterns with reduction in r and S.

V3 has an rS pattern with increase in S.

V4 has an Rs pattern.

V5 and V6 have qRs patterns with increase of q and R in V6.

T is inverted in VI, reduced in V2 and V3 and increased in V4 to V6. P is inverted in VI.

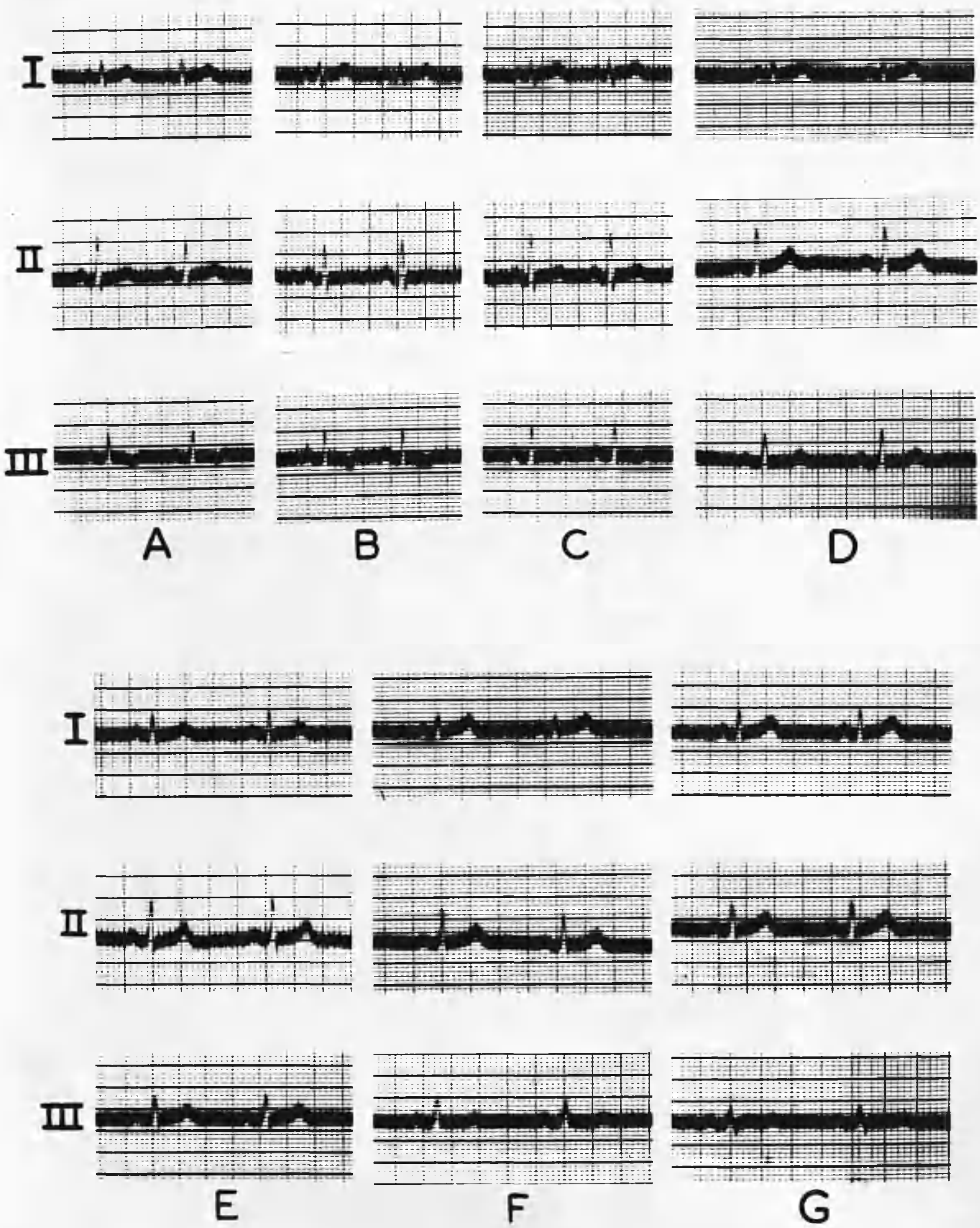
Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

The patterns are similar to the control but V4 to V6 show slight increase in q,R and T.

There has been some forward rotation of the apex.

STANDARD LIMB LEADS



UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and a Qr pattern. It tends to face the back of the heart.

aVL has inverted P and slightly diphasic T waves and a qs pattern. It probably tends to face the back of the heart.

aVF has upright P and T waves and an Rs pattern. It tends to face the epicardial surface of the right ventricle.

The heart is vertical with backward rotation of the apex.

Vertical Rotation.

A: Sitting.

aVR shows increase in Q and r; T is less inverted.
aVL has a QS pattern; T is upright.
aVF shows increase in s; T is reduced.

B: Standing.

aVR has a Qr pattern with increase in r; T is much less inverted.

aVL has a QS pattern; T is increased.

aVF has an Rs pattern with increase in s; T is slightly inverted.

C: 45^o head up.

The changes are similar to those in B but are of less degree. In particular T in aVR is more negative and T in aVF is still upright.

In A,B and C the heart has become more vertical and there has probably been clockwise rotation.

Horizontal Rotation.

E: Right Lateral.

aVR has an rSr' pattern and more deeply inverted P and T waves.

aVL has a qr pattern; P is less inverted; T is flat.

aVF has an Rs pattern with reduction in R and increase in s.

The heart has become more horizontal.

F: Left Lateral.

aVL has a small vibratory qrsr' pattern.
aVF has reduction in R and T.
The heart has probably become less vertical.

G: Prone.

aVL has upright P and T and a qR pattern.
aVF has an Rs pattern with reduction in R.
The heart has become horizontal.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have RS patterns.
V3 has an Rs pattern.
V4 and V5 have qRs patterns.
V6 has an Rs pattern.
P and T are upright in all leads.
There is moderate counter-clockwise rotation.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns with increase in S.
V3 has an RS pattern.
V4 and V5 have qRs patterns with increase in s.
V6 has an Rs pattern with reduction in R and increase in s.
T is reduced in all leads.
There has been clockwise rotation of the heart.

B: Standing.

VI to V3 have rS patterns with increase in S.
V4 to V6 have qRs patterns with increase in q and s and decrease in R.
T is reduced in all leads.
P is diphasic in VI and V2.
There has been further clockwise rotation and the heart has also become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S.
V2 has an Rs pattern.
V3 to V5 have qRs patterns with reduction of R and s in V5.
V6 has an Rs pattern with reduction of R.
T is increased in VI and reduced in all others.
Some displacement to the right has occurred, with backward rotation of the apex.

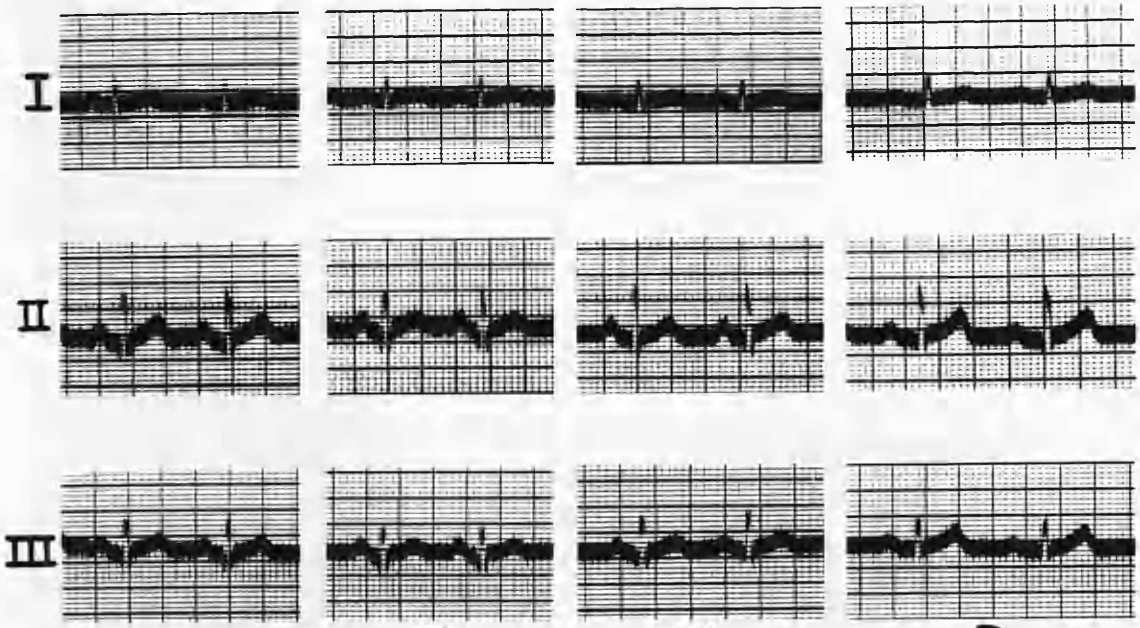
F: Left Lateral.

VI shows reduction in R,S and T; V2 and V3 show increase in R and S; V4 to V6 show increase in R.
Some displacement to the left has occurred.

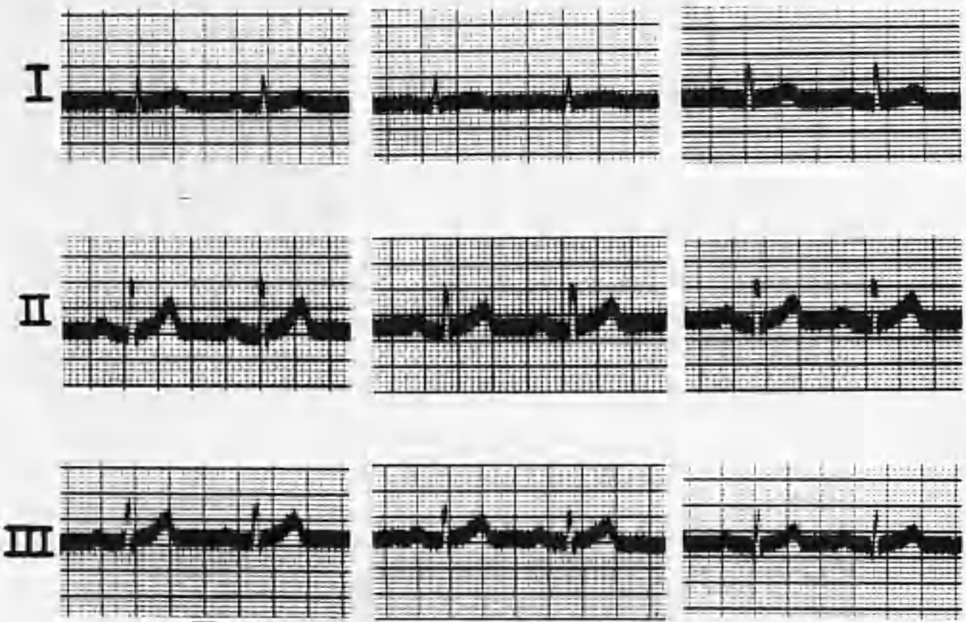
G: Prone.

The patterns are similar to the control but R is reduced in V4 to V6 and T is reduced in all leads.
The heart has become more horizontal.

STANDARD LIMB LEADS



A B C D



E F G

NORMAL.

J.S.

Age 45 years.

STANDARD LIMB LEADS.

D: Supine.

All leads have upright P and T waves and a qRs pattern.

There is no axis deviation.

Vertical Rotation.

A: Sitting.

The patterns remain similar to the control but q and s are increased in lead II; q,R and s are increased in lead III; T is reduced in leads II and III.

B: Standing.

Lead II shows increase in q and s and reduction in R; lead III shows increase in q and s; T is reduced in leads II and III.

C: 45^{o} head up.

Lead II shows increase in R and s; lead III shows increase in q,R and s. T is reduced in leads II and III.

Horizontal Rotation.

E: Right Lateral.

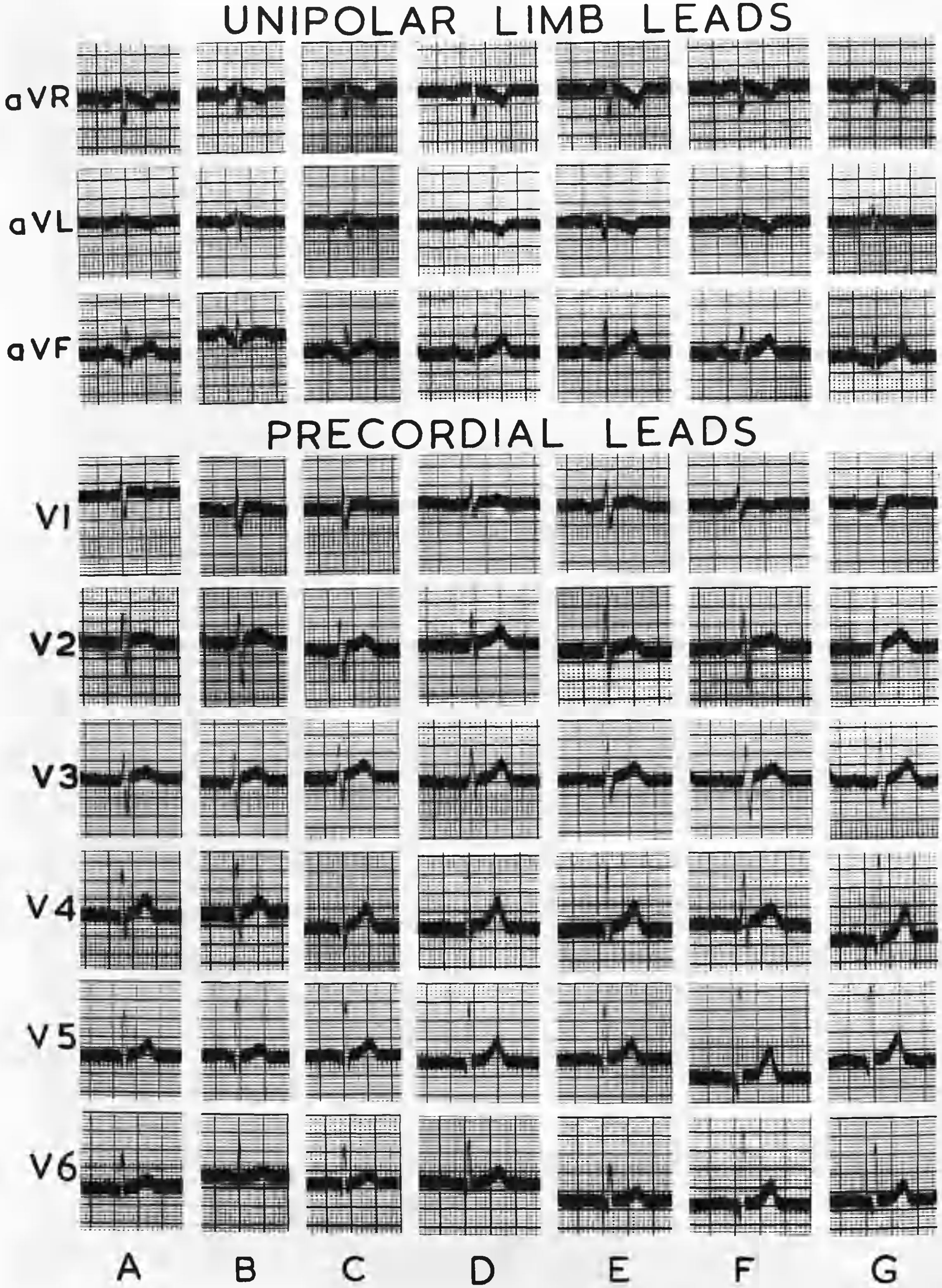
Lead I shows increase in q and R; lead III shows an Rs pattern with increase in R. T is increased in all.

F: Left Lateral.

Lead II shows reduction in R; lead III shows increase in s. T is unaltered.

G: Prone.

Lead I shows increase in R; lead II shows decrease in R; lead III shows increase in q. T is increased in lead I and decreased in lead III.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

aVL has inverted P and T waves and an rsr' pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is semi-vertical, with forward rotation of the apex.

Vertical Rotation.

A: Sitting.

aVR shows reduction in T.

aVL has an rSr' pattern and a less inverted T.

aVF has a qRs pattern with increase in q and s; T is reduced.

The heart has become more vertical.

B: Standing.

aVR shows less inverted T and increase in r'.

aVL shows an rSr' pattern with increase in r and S; T is flat.

aVF shows a qRs pattern with increase in q and s and decrease in R; T is further reduced.

The heart has become more vertical.

C: 45° head up.

The changes are intermediate between A and B.

Horizontal Rotation.

E: Right Lateral.

aVR shows increase in S and more deeply inverted T.

aVL has an rSr' pattern.

aVF shows a qRs pattern with increase in R; T is increased.

The heart has become more vertical.

F: Left Lateral.

aVL has an rSr' pattern.

The heart is slightly more vertical.

G: Prone.

aVL has a qRSr' pattern; T is less inverted.

aVF has a qRs pattern with reduction in R.

The heart has become horizontal with forward rotation of the apex.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have Rs patterns.
V4 to V6 have qRs patterns.
T is upright in all leads.
There is moderate counter-clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.

Leads VI to V3 have RS patterns.
V4 to V6 have qRs patterns with reduction in R and increase in s.
T is reduced in all leads.
There has been clockwise rotation of the heart.

B: Standing.

VI to V3 have RS patterns.
V4 to V6 have qRs patterns with increase in q and s.
T is reduced in all leads.
There has been clockwise rotation of the heart and it has also become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

VI to V3 have RS patterns with increase in R.
V4 to V5 have qRs patterns.
V6 has a qR pattern.
Some displacement to the right has occurred.

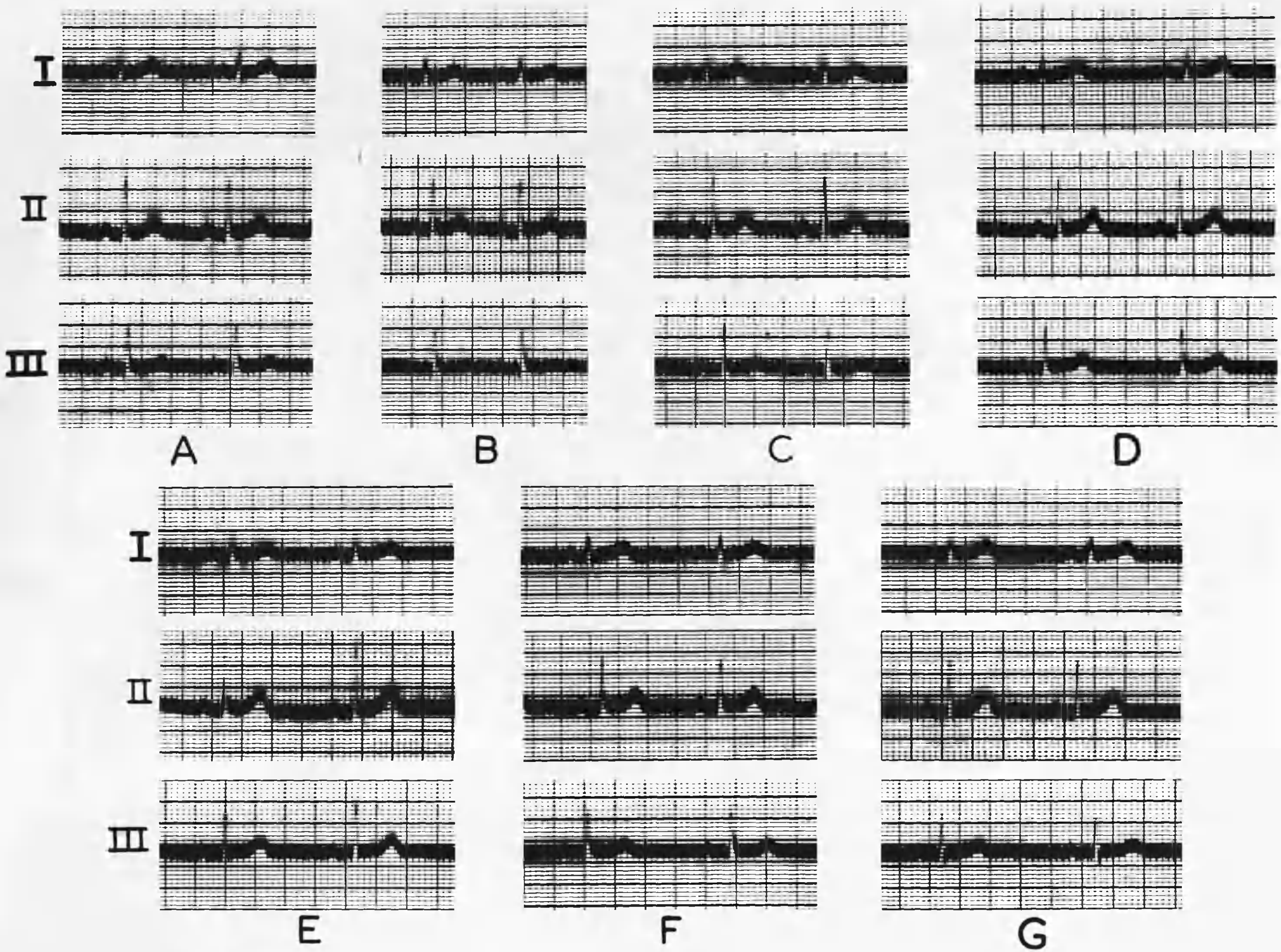
F: Left Lateral.

VI to V3 have RS patterns and T is inverted in VI.
V4 has an Rs pattern.
V5 and V6 have qRs patterns with increase in q and R.
Some displacement to the left has occurred along with counter-clockwise rotation.

G: Prone.

R is increased in all leads and V5 and V6 have qR patterns.
Some counter-clockwise rotation has occurred.

STANDARD LIMB LEADS



NORMAL. D.L.

Age 3I years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has an Rs pattern.
Leads II and III have qR patterns.
P and T are upright in all.
There is a tendency to right axis deviation.

Vertical Rotation.

A: Sitting.

Leads II and III show increase in P and decrease in T.

B: Standing.

Lead I shows decrease in T.
Lead II shows increase in P and decrease in T.
Lead III shows increase in P and q; T is flat.

C: 45° head up.

Leads II and III show increase in P and decrease in T.

Horizontal Rotation.

E: Right Lateral.

Lead I has a qR pattern with increase in R.
Lead II shows increase in R and T.
Lead III shows a qRs pattern; T is increased.

F: Left Lateral.

Lead I shows increase in s.
Lead II shows decrease in R and T.
Lead III shows decrease in R and T.

G: Prone.

Lead I has a qR pattern.
Lead II has a qRs pattern.
Lead III has a qRs pattern with reduction in R; T is reduced.

In E and G there has been a slight shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rS pattern. It faces the cavity of the right ventricle.

aVL has shallow inverted P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

aVR has less inverted T.
aVL shows increase in S; T is flat.
aVF shows increase in R; T is reduced.
The heart has become more vertical.

B: Standing.

aVR shows less inverted T.
aVL shows increase in S; T is flat.
aVF shows increase in P, q and R; T is practically flat.
The heart has become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

aVR shows deeper S and T.
aVL shows deeper S and T.
aVF shows increase in R and T.

F: Left Lateral.

aVR shows smaller S and less inverted T.
aVL shows less inverted T.
aVF shows reduction in T.

G: Prone.

aVR shows more inverted T.
aVL has an rSr' pattern with reduction in S.
aVF has an Rs pattern; T is reduced.
The heart has become less vertical.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns.
P and T are upright in all leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V4 have rS patterns.
V5 has an Rs pattern.
V6 has a qRs pattern with reduction in R.
T is increased in VI and reduced in all other leads.
There has been further clockwise rotation of the heart.

B: Standing.

VI to V4 have rS patterns with increase in S.
V5 has an Rs pattern.
V6 has a qRs pattern with increase in s.
There has been further clockwise rotation of the heart.

C: 45^{o} head up.

The changes are very similar to those in B.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S; T is increased.
V2 has an rS pattern with decrease in S; T is decreased.
V3 and V4 have RS patterns with decrease in S.
V5 has an Rs pattern with decrease in R, and V6 has a qRs pattern with decrease in q and R; T is decreased in both.
Displacement to the right has occurred along with backward rotation of the apex.

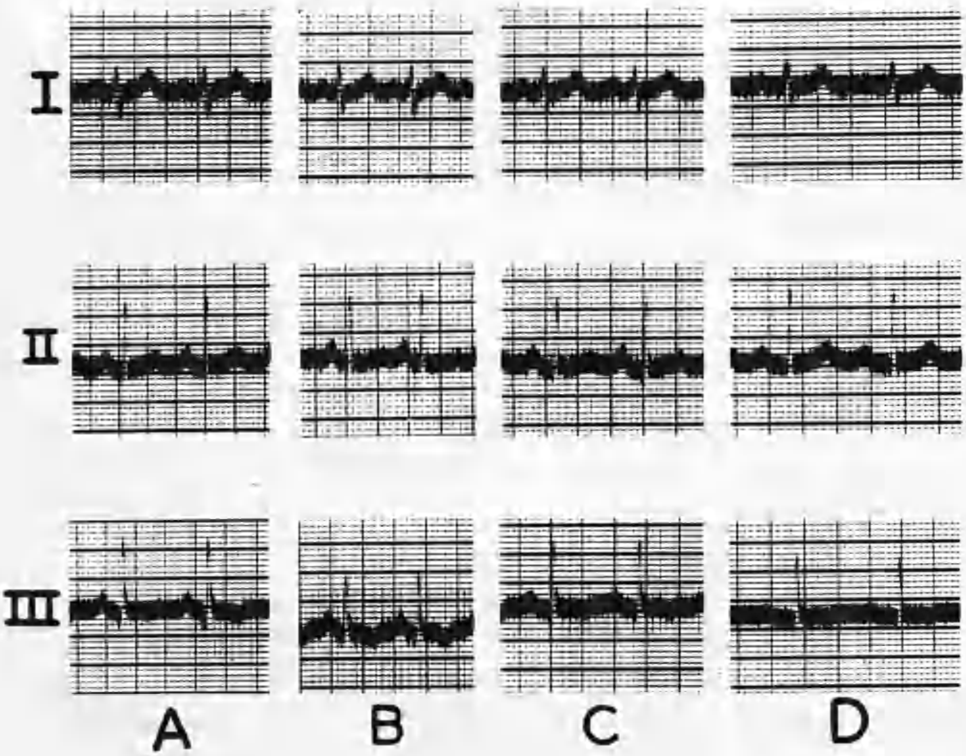
F: Left Lateral.

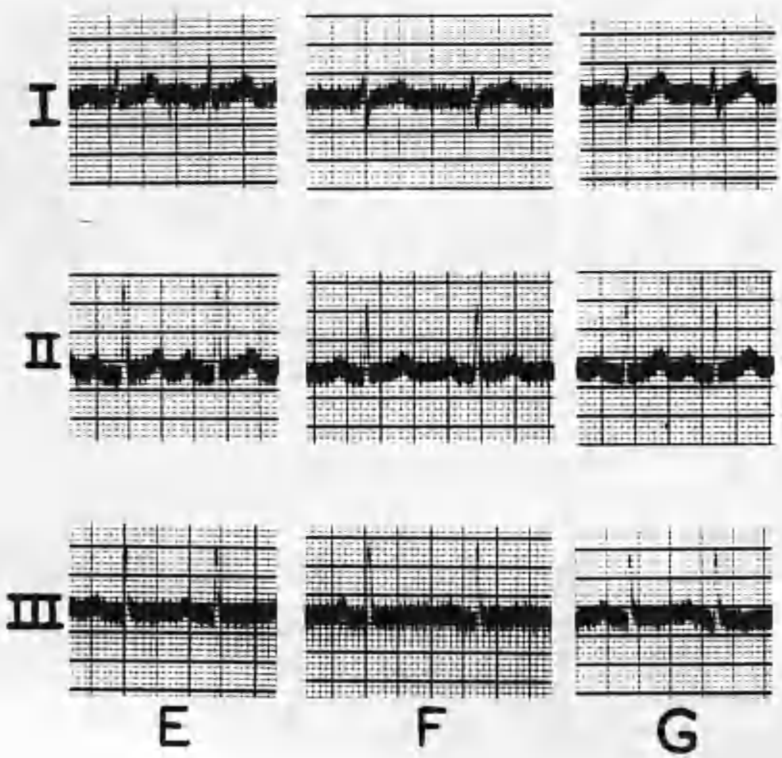
VI to V3 are similar to the control.
V4 has an RS pattern with increase in R.
V5 has a qRs pattern with increase in q and R and V6 has a qR pattern with increase in R; T is increased in both.
There has been forward rotation of the apex.

G: Prone.

VI has an rS pattern with increase in S; T is increased. V2 has an rS pattern with decrease in S.
There has been slight counter-clockwise rotation.

STANDARD LIMB LEADS





CASE NO. 28 PLATE 158a

NORMAL. Miss H.L.

Age 21 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an RS pattern.

Lead II has upright P and T waves and a qRs pattern.

Lead III has upright P and shallow diphasic T waves and a qR pattern.

There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I shows increase in R,S and T.

Lead II shows increase in P and decrease in T.

Lead III shows increase in P,q and R; T is still diphasic but more negative.

B: Standing.

Lead II shows further increase in P; T is now flat.

Lead III shows increase in P and q; T is inverted.

C: 45° head up.

The changes are intermediate between A and B.

Horizontal Rotation.

E: Right Lateral.

Lead I has an Rs pattern with increase in R; T is increased.

Lead II shows increase in P,R and T.

Lead III shows increase in P; T is slightly positive.

There has been a shift of the QRS axis to the left.

F: Left Lateral.

Lead I has an RS pattern with increase in S.

Lead II shows decrease in R.

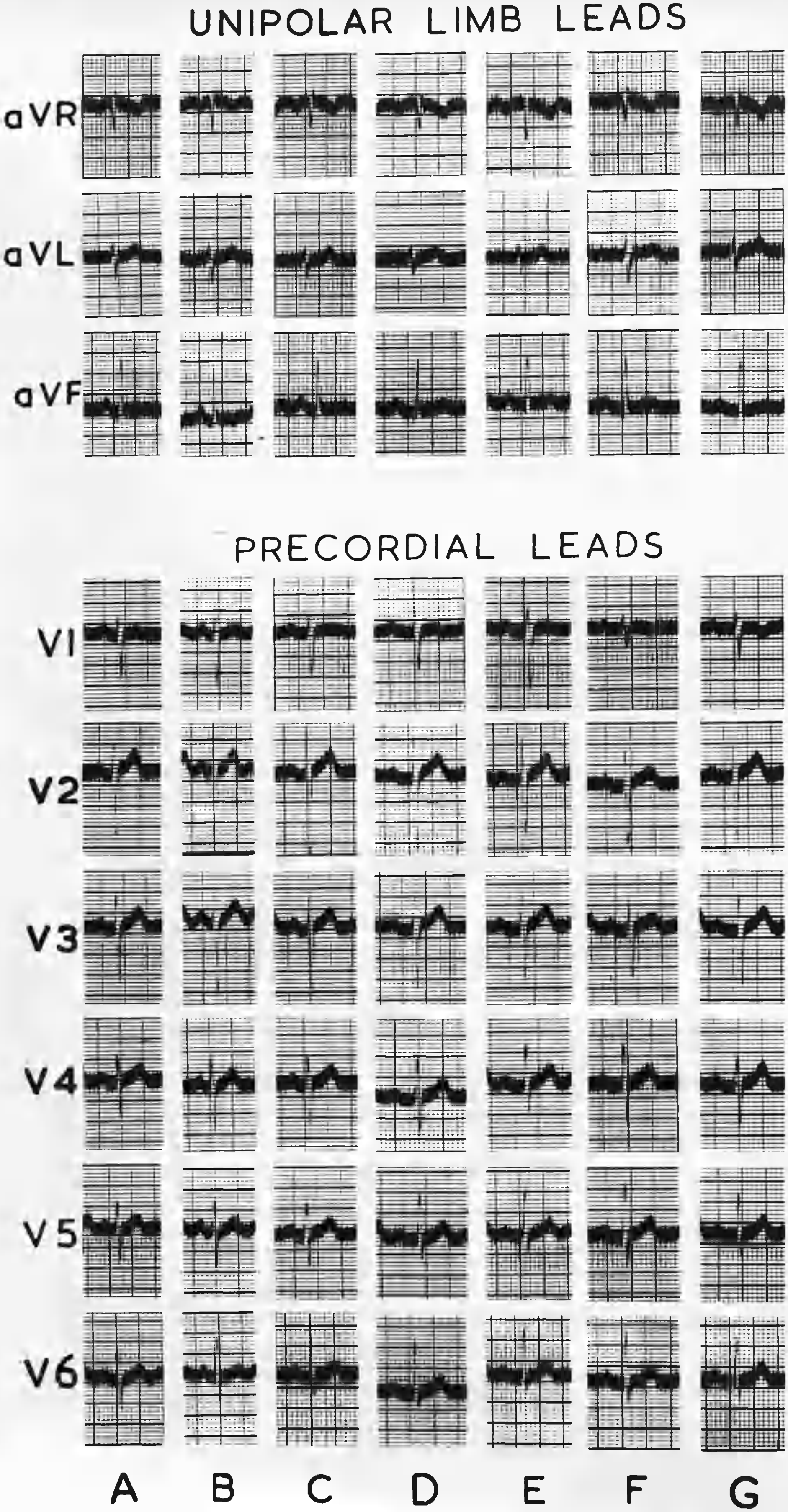
Lead III shows increase in R; T is flat.

There has been a shift of the QRS axis to the right.

G: Prone.

Lead I has an RS pattern with increase in both R and S; T is increased.

Lead III shows increase in q; T is slightly inverted.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

aVL has flat P and upright T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

aVR shows slight decrease in T.
aVL shows increase in S and T.
aVF shows increase in q; T is practically flat.
The heart has become slightly more vertical.

B: Standing.

aVR shows less inverted T.
aVL shows increase in S.
aVF shows increase in P and q; T is slightly inverted.
The heart has become more vertical.

C: 45° head up.

The changes are intermediate between A and B.

Horizontal Rotation.

E: Right Lateral.

aVR shows more deeply inverted P and T and a QS pattern. It now faces the cavity of the left ventricle.

aVL shows an RS pattern; T is increased.

aVF shows increase in T.

There has possibly been some counter-clockwise rotation.

F: Left Lateral.

aVR shows less inverted P and T and a Qr pattern.

aVL shows an rS pattern with increase in both r and S.

aVF shows increase in q.

The heart has become more vertical.

G: Prone.

aVR shows more deeply inverted T.

aVL shows an RS pattern with increase in S; T is increased.

aVF shows decrease in T.

The heart has become slightly less vertical.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qRs pattern.
P is upright in all leads.
T is slightly diphasic in VI and upright in all other leads.

There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns.
V4 to V6 have RS patterns with reduction in R.
There has been further clockwise rotation.

B: Standing.

The patterns are similar to those in A but S is deeper in VI to V4 and R is greater in V6.

Further clockwise rotation has occurred and the heart has also become more vertical.

C: 45° head up.

The changes are similar to those in B.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S.
V2 to V4 have RS patterns with decrease in S.
V5 has an Rs pattern with increase in R.
V6 has a qRs pattern.
Some displacement to the right has occurred.

F: Left Lateral.

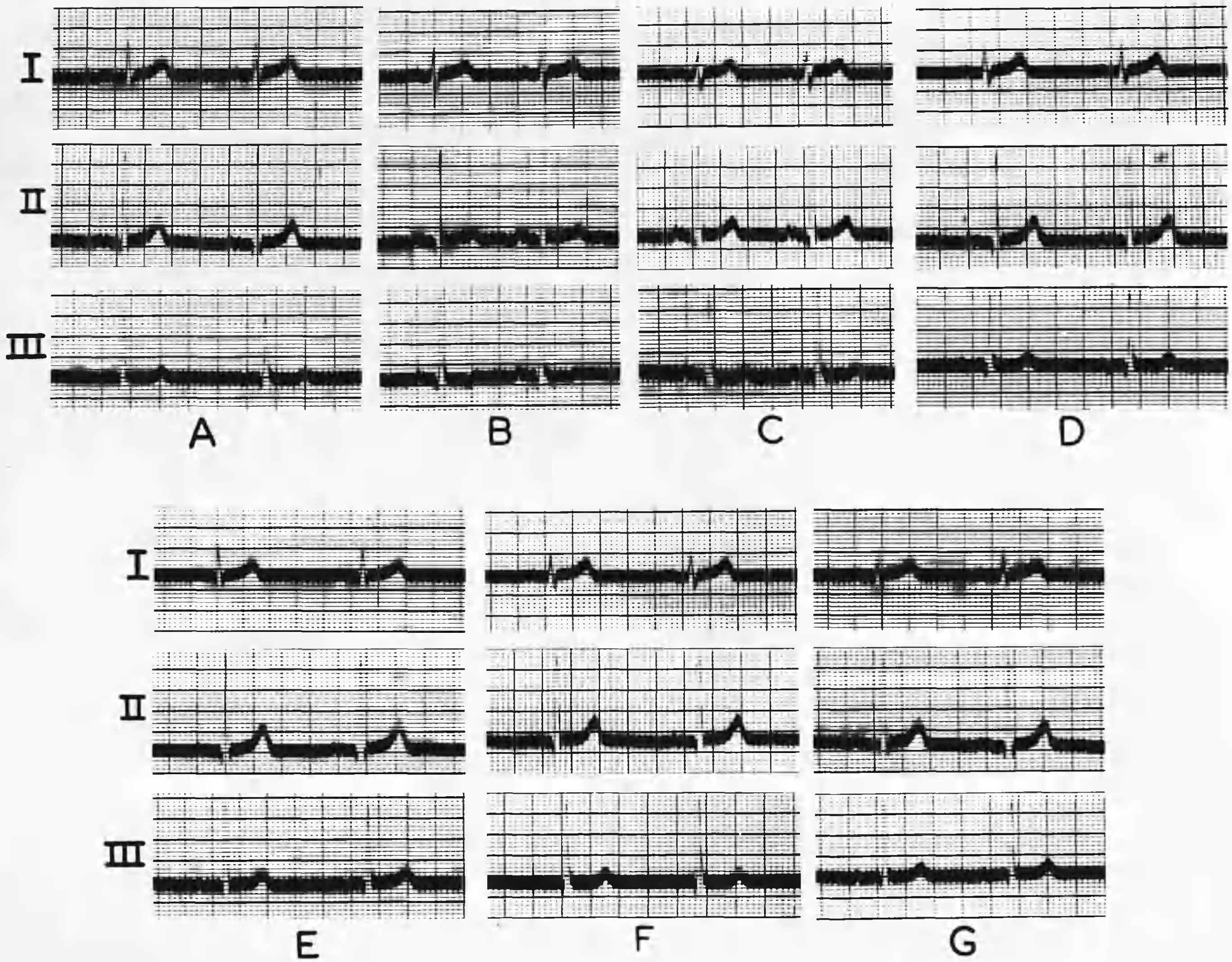
VI has an RS pattern with reduction in both R and S; T is slightly inverted.
V2 to V4 have RS patterns.
V5 has an Rs pattern with increase in R and s.
V6 has a qRs pattern.
Some displacement to the left has occurred.

G: Prone.

The patterns are very similar to the control series but r and S are reduced in VI and T is inverted; R is also reduced in V4 to V6.

The heart has become slightly less vertical.

STANDARD LIMB LEADS



NORMAL.

D.W.

Age 20 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an Rs pattern.

Lead II has diphasic P and upright T waves and a qRs pattern.

Lead III has diphasic P and upright T waves and a qR pattern.

There is slight right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I shows increase in R and T.
Lead II shows increase in R and T.
Lead III shows decrease in R and T.

B: Standing.

Lead I has an RS pattern; T is reduced.

Lead II has taller bifid P; R is increased and s reduced; T is reduced.

Lead III has upright P; R is increased;T is diphasic but mainly negative.

There has been a shift of the QRS axis to the right.

C: 45^o head up.

The changes are similar to those in B but are less in degree. In lead III T remains upright.

There has been a shift of the QRS axis to the right.

Horizontal Rotation.

E: Right Lateral.

Lead I has a qRs pattern with reduction in s; T is reduced.

Lead II shows increase in s and T.

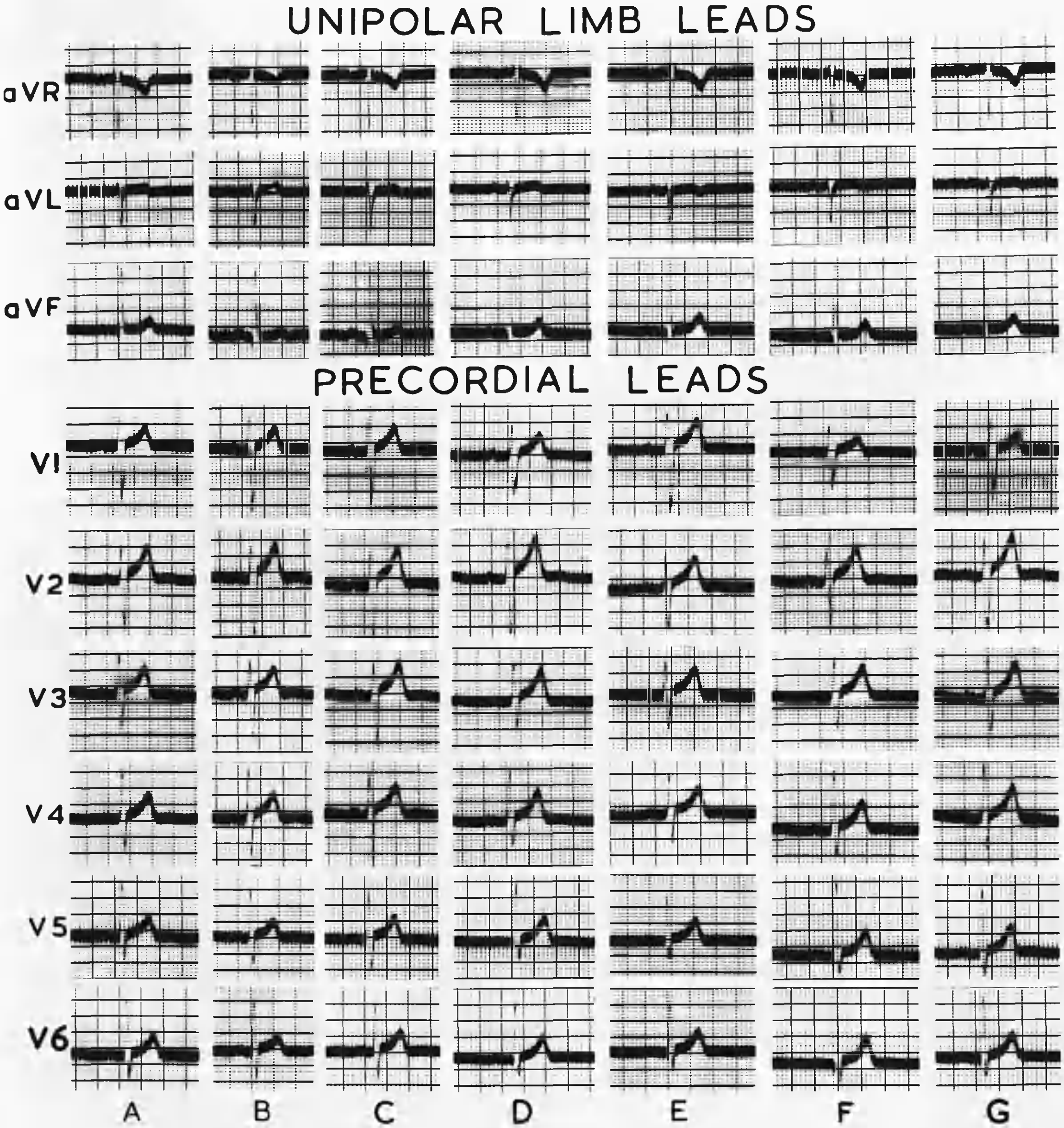
Lead III has a qRs pattern with increase in R; T is increased.

F: Left Lateral.

Lead III shows increase in R and T.

G: Prone.

Lead I shows reduction in R,s and T.
Lead II shows increase in s; T is reduced.
Lead III has a qRs pattern.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
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A
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UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It probably faces the cavity of the right ventricle.

aVL has upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has diphasic P and upright T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

aVR shows an inverted bifid P and less inverted T wave; S is increased.

aVL has diphasic P; S is increased.

aVF has upright bifid P; T is reduced.

B: Standing.

aVR shows inverted bifid P and less inverted T; S is increased and r' decreased.

aVL has inverted P; S is increased.

aVF has upright bifid P; R is increased; T is reduced.

The heart has become more vertical.

C: 45° head up.

The changes are similar to those in B.

Horizontal Rotation.

E: Right Lateral.

aVR shows increase in r and S; T is deeper.

aVL shows decrease in r and increase in S; T is slightly diphasic.

aVF shows increase in R,s and T.

F: Left Lateral.

aVR shows decrease in r'.

aVL shows increase in S.

aVF shows increase in T.

G: Prone.

The patterns are similar to the control series.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have RS patterns.
V4 has an Rs pattern.
V5 and V6 have qRs patterns.
P is diphasic in VI and upright and bifid in all other leads; T is upright in all leads.
There is moderate clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns.
V3 has an RS pattern.
V4 and V5 have Rs patterns.
V6 has a qRs pattern with increase in s.
T is slightly reduced in all.
There has been further clockwise rotation.

B: Standing.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have Rs patterns with increase in s.
T is reduced in all leads.
There has been further clockwise rotation.

C: 45° head up.

The changes are similar to those in B but are less in degree.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S; T is increased.
V2 and V3 have RS patterns.
V4 has an RS pattern with reduction in R.
V5 has an Rs pattern.
V6 has a qRs pattern with reduction in R.
Displacement to the right has occurred along with some backward rotation of the apex.

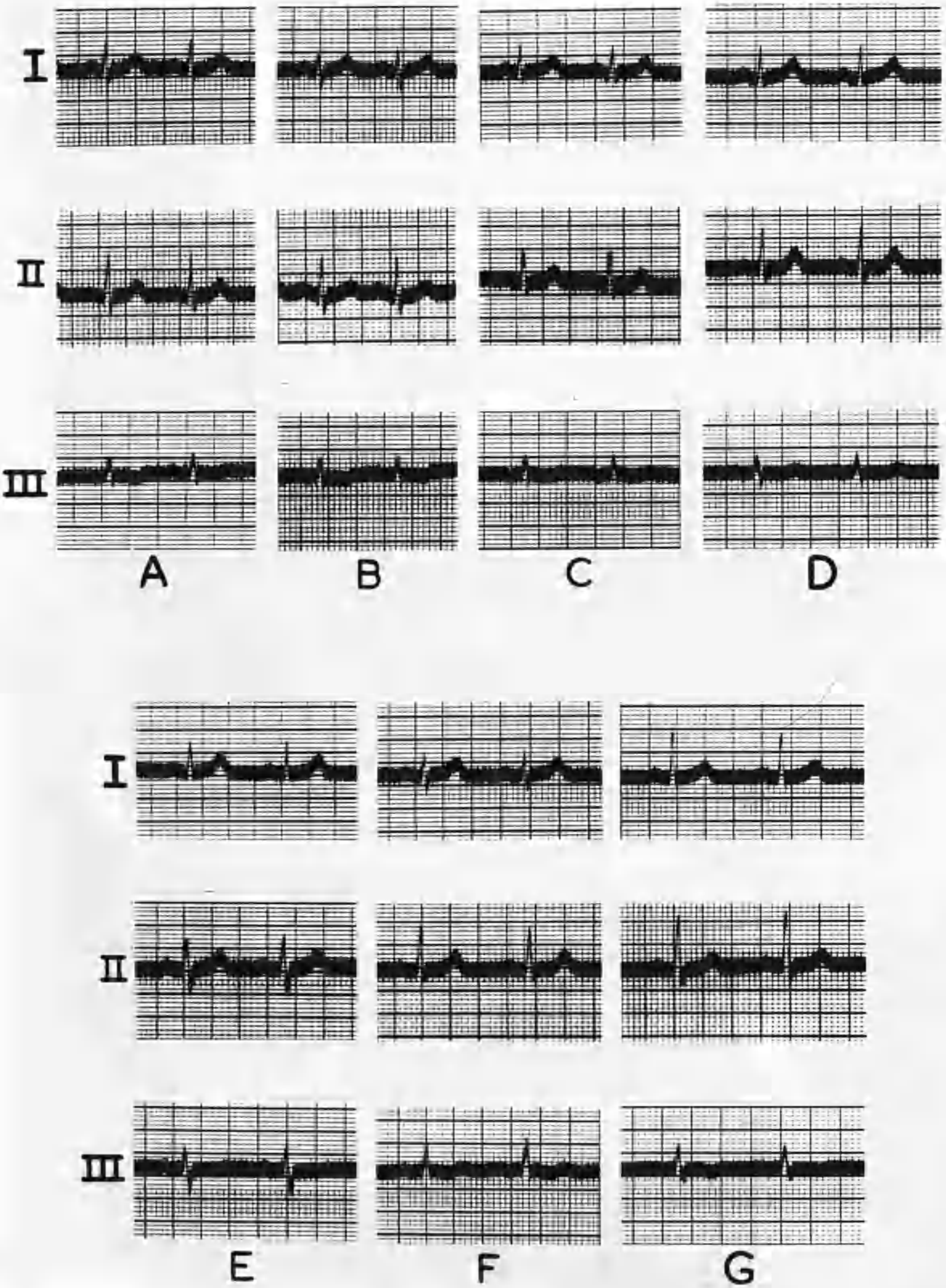
F: Left Lateral.

VI and V2 have RS patterns with reduction in R and S; T is reduced.
V4 has an Rs pattern with increase in R.
V5 and V6 have qRs patterns with increase in q,R and s; T is increased.
Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

VI to V3 are similar to the control.
V4 to V6 are similar to F but less in degree.
There has been forward rotation of the apex.

STANDARD LIMB LEADS



NORMAL. R.C.

Age 28 years.

STANDARD LIMB LEADS.

D: Supine.

Leads I and II have upright P and T waves and a qRs pattern.

Lead III has diphasic P waves, diphasic but mainly upright T waves and a qRs pattern.

Vertical Rotation.

A: Sitting.

Lead I has an Rs pattern with increase in s; P and T are reduced.

Lead II has a qRs pattern with increase in R and s; P and T are reduced.

Lead III has slightly inverted T waves.

B: Standing.

Lead I has a qRS pattern with reduction in R; T is reduced.

Lead II has a qRs pattern with increase in q and s; T is reduced.

Lead III has a qRs pattern with reduction in s; T is inverted.

There has been a shift of the QRS axis to the right.

C: 45° head up.

The changes are similar to those in B but are less in degree.

Horizontal Rotation.

E: Right Lateral.

Lead I shows slight reduction in q and s.

Lead II has an RS pattern with reduction in R.

Lead III has an RS pattern with increase in R; T is low upright.

There has been a shift of the QRS axis to the left.

F: Left Lateral.

Lead I has an RS pattern with reduction in R.

Lead II has a qRs pattern with increase in R.

Lead III has a qRs pattern with increase in R and reduction in s.

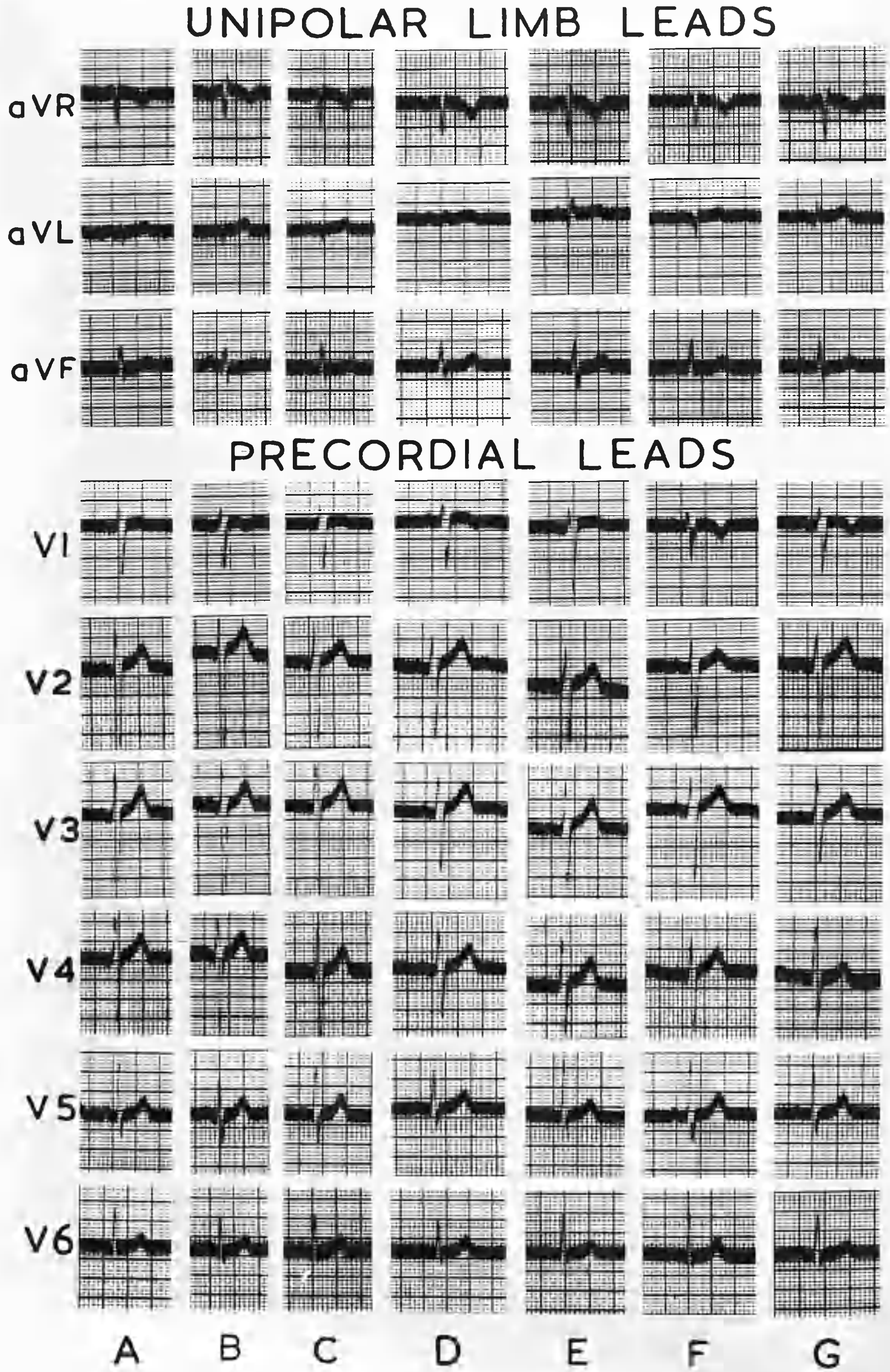
There has been a shift of the QRS axis to the right.

G: Prone.

Lead I has a qRs pattern with increase in R; T is reduced.

Lead II has a qRs pattern with increase in R and s; T is reduced.

Lead III has a qRs pattern with increase in R; P and T are slightly inverted.


UNIPOLAR LIMB LEADS
aVR
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PRECORDIAL LEADS
V1
V2
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UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It probably faces the cavity of the right ventricle.

aVL has upright P and T waves and a qrsr' pattern.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is semi-vertical.

Vertical Rotation.

A: Sitting.

aVR shows less inverted P and T waves.

aVL has an rS pattern.

aVF has a qRs pattern; T is reduced.

The heart has become more vertical.

B: Standing.

aVR has an rSr' pattern with increase in S and r'; T is less inverted.

aVL has an rS pattern; P is diphasic and T is increased.

aVF has a qRs pattern with decrease in R and increase in s; P is increased and T is reduced.

The heart has become more vertical and there has been clockwise rotation.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

aVR has an rSr' pattern with increase in S and r'; T is slightly more inverted.

aVL has a qR pattern. It tends to face the epicardial surface of the left ventricle.

aVF has an RS pattern. It tends to face the epicardial surface of the right ventricle.

The heart has become horizontal.

F: Left Lateral.

aVR shows reduction in P,S,r' and T.

aVL has a splintered QS pattern; P is reduced.

aVF has a qRs pattern with reduction in s.

The heart has probably become more vertical.

G: Prone.

aVR shows increase in S and r'; T is less inverted.

aVL has a splintered qR pattern; T is increased.

The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 and V6 have qRs patterns.
P is upright in all leads.
T is diphasic in VI and upright in all other leads.
There is moderate clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns with increase of S in V2 and V3.
V4 has an RS pattern with increase in S.
V5 and V6 have qRs patterns with increase in R.
There has been further clockwise rotation.

B: Standing.

VI to V4 have rS patterns with increase in S.
V5 and V6 have qRs patterns with increase in q and s.
T is inverted in VI.
There has been further clockwise rotation and the heart has become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in S.
V2 to V4 have RS patterns.
V5 and V6 have qRs patterns with increase in R.
T is upright in VI.
Some displacement to the right has occurred.

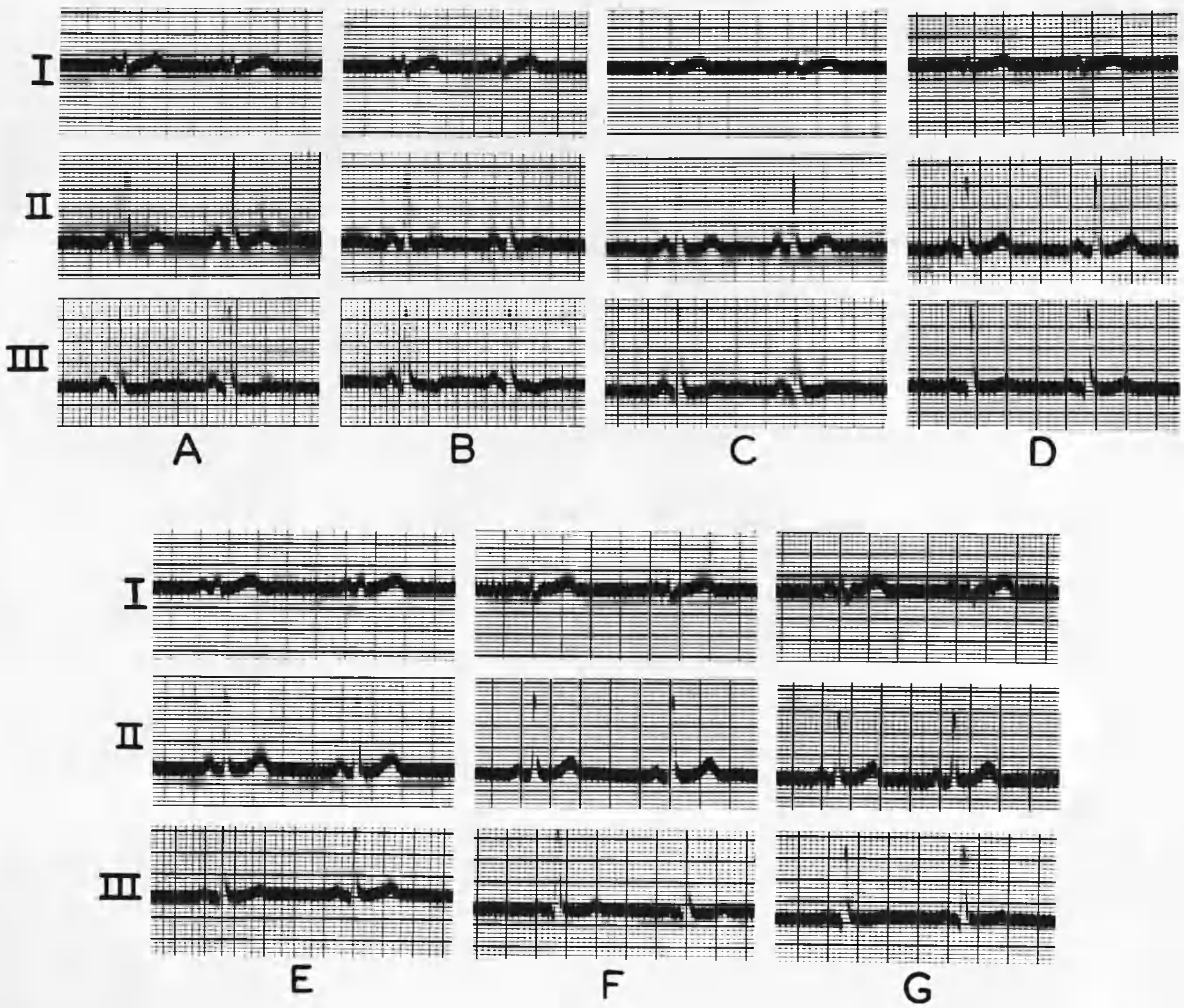
F: Left Lateral.

VI to V3 have rS patterns with reduction of r and S in VI, and inversion of T.
V4 has an RS pattern with reduction in R and increase in S.
V5 and V6 have qRs patterns with increase in R and s.
Some displacement to the left has occurred, with forward rotation of the apex.

G: Prone.

The patterns are similar to the control series apart from inversion of T in VI and increase of R in V4 to V6.

STANDARD LIMB LEADS



NORMAL.

T.L.

Age 27 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has a small Rs pattern.
Lead II has an R pattern.
Lead III has a qR pattern.
P and T are upright in all leads.
There is right axis deviation.

Vertical Rotation.

A: Sitting.

Lead I has an RS pattern with slight increase in R.
Lead II shows increase in P and decrease in T.
Lead III shows increase in q; T is diphasic, and the RT interval is slightly depressed. P is increased.

B: Standing.

Lead I shows increase in s.
Lead II shows increase in P; T is practically flat.
Lead III shows increase in P and q; T is inverted and the RT interval is slightly depressed.

C: 45° head up.

Lead I shows increase in s.
Lead II shows increase in P and decrease in T.
Lead III shows increase in P and q; T is reduced and the RT interval is slightly depressed.

Horizontal Rotation.

E: Right Lateral.

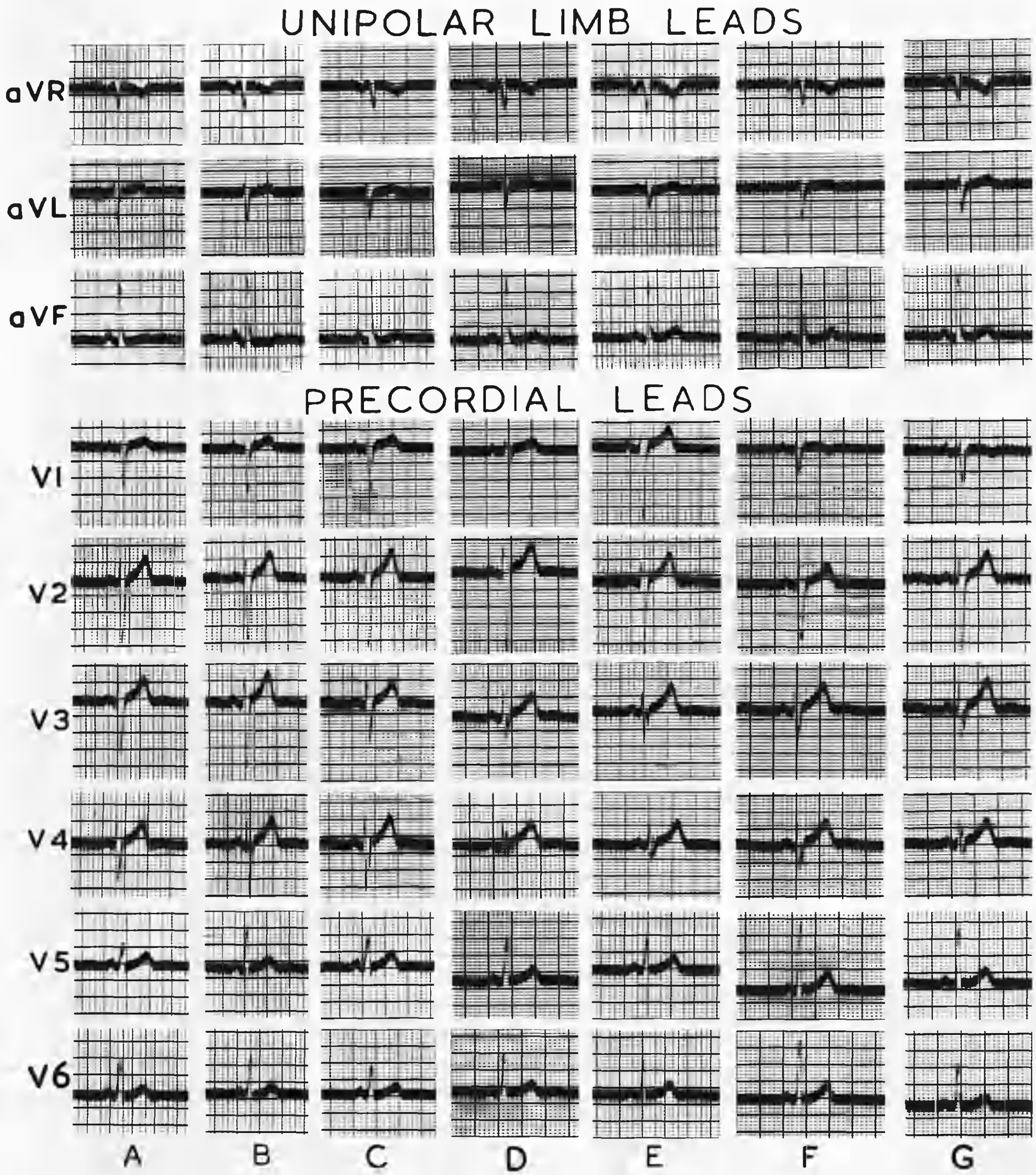
Lead I shows increase in P,R and T.
Lead II shows increase in P,R and T.
Lead III shows reduction in R.
There has been a shift of the QRS axis to the left.

F: Left Lateral.

Lead I has an RS pattern.
Lead II shows increase in R.
Lead III shows increase in R.
There has been a shift of the QRS axis to the right.

G: Prone.

Lead I shows increase in R,s and T.
Lead II shows reduction in R.
Lead III shows reduction in R and T.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
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UNIPOLAR LIMB LEADS

D: Supine.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has low upright P and T waves and an rS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qR pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

aVR shows reduction in P, QS and T.
aVL shows increase in S and T.
aVF shows increase in P and reduction in T.
The heart has become more vertical.

B: Standing.

aVR shows reduction in QS and T.
aVL shows increase in S and T.
aVF shows increase in P, q, R; T is slightly inverted, and the RT interval is slightly depressed.
The heart has become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree. In particular T in aVF remains upright.

Horizontal Rotation.

E: Right Lateral.

aVR shows increase in QS; P and T are more inverted.
aVL shows increase in P and decrease in S.
aVF shows reduction in R and increase in T.
The heart has become less vertical.

F: Left Lateral.

aVR shows a Qr pattern. It now tends to face the back of the heart.
aVL shows increase in S.
aVF shows increase in R.
The heart has become more vertical.

G: Prone.

aVR has a Qr pattern; P and T are more deeply inverted.
aVL shows increase in T.

PRECORDIAL LEADS.

D: Supine.

VI and V2 have rS patterns.
V3 has a splintered RS pattern.
V4 has an RSR'S' pattern.
V5 has an Rs pattern.
V6 has an R pattern.
P and T are upright in all leads.
There is marked clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.

VI to V3 have rS patterns.
V4 has an RS pattern with slurred S.
V5 and V6 have Rs patterns with slurred R.
There has been clockwise rotation.

B: Standing.

VI to V4 have rS patterns.
V5 and V6 have Rs patterns with slurred R.
There has been further clockwise rotation.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

VI and V2 have rS patterns with increase of r and S in VI; T is increased in VI.
V5 and V6 show reduction in R.
Some displacement to the right has occurred.

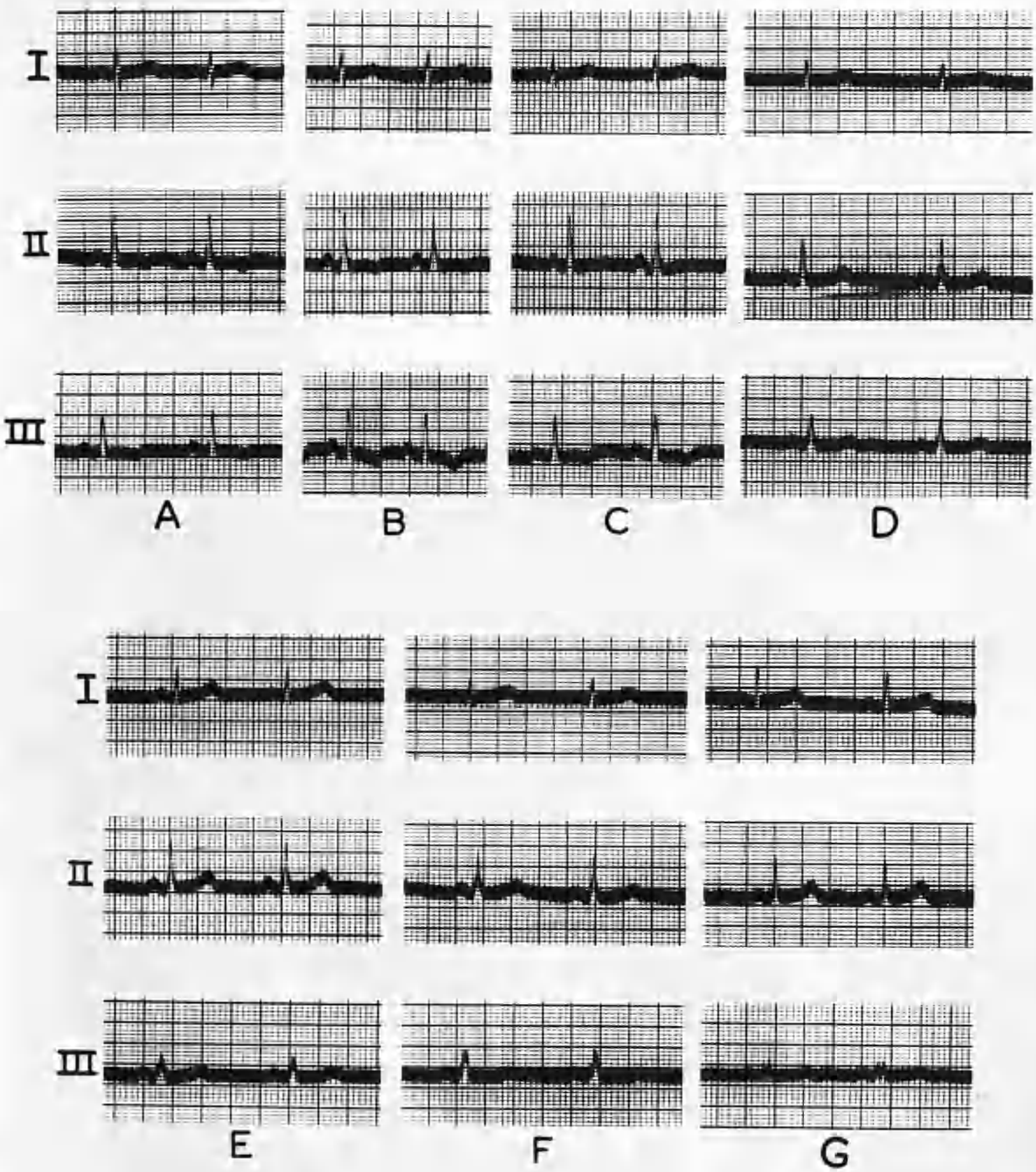
F: Left Lateral.

VI and V2 have rS patterns with reduction in r and S; T is slightly inverted in VI.
V3 has an rS pattern with slurred S.
V4 has a splintered RS pattern.
V5 has an Rs pattern with increase in R; T is increased.
V6 shows increase in R and T.
Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

VI has slightly inverted T.
V5 and V6 show increase in R.
Otherwise the patterns are similar to the control.
The heart has probably become less vertical and there has been some forward rotation of the apex.

STANDARD LIMB LEADS



CASE NO. 32 PLATE 162a

NORMAL.

A.McL.

Age 17 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and a qRs pattern.

Leads II and III have upright P and T waves and R patterns.

Vertical Rotation.

A: Sitting.

Lead I has a qRS pattern; T is increased.
Lead II shows increase in R; T is inverted.
Lead III shows increase in R; T is inverted.
There has been a shift of the QRS axis to the right.

B: Standing.

Lead I has a qRs pattern with increase in R and s.

Lead II shows increase in P and R; the RT interval is slightly depressed and T is inverted.

Lead III shows increase in P and has a qR pattern with increase in R; the RT interval is slightly depressed and T is deeply inverted.

There has been a shift of the QRS axis to the right.

C: 45° head up.

Lead I has a qRs pattern with increase in s.
Lead II shows increase in P and R; T is flat.
Lead III shows increase in P and R; the RT interval is slightly depressed and T is inverted.
There has been a shift of the QRS axis to the right.

Horizontal Rotation.

E: Right Lateral.

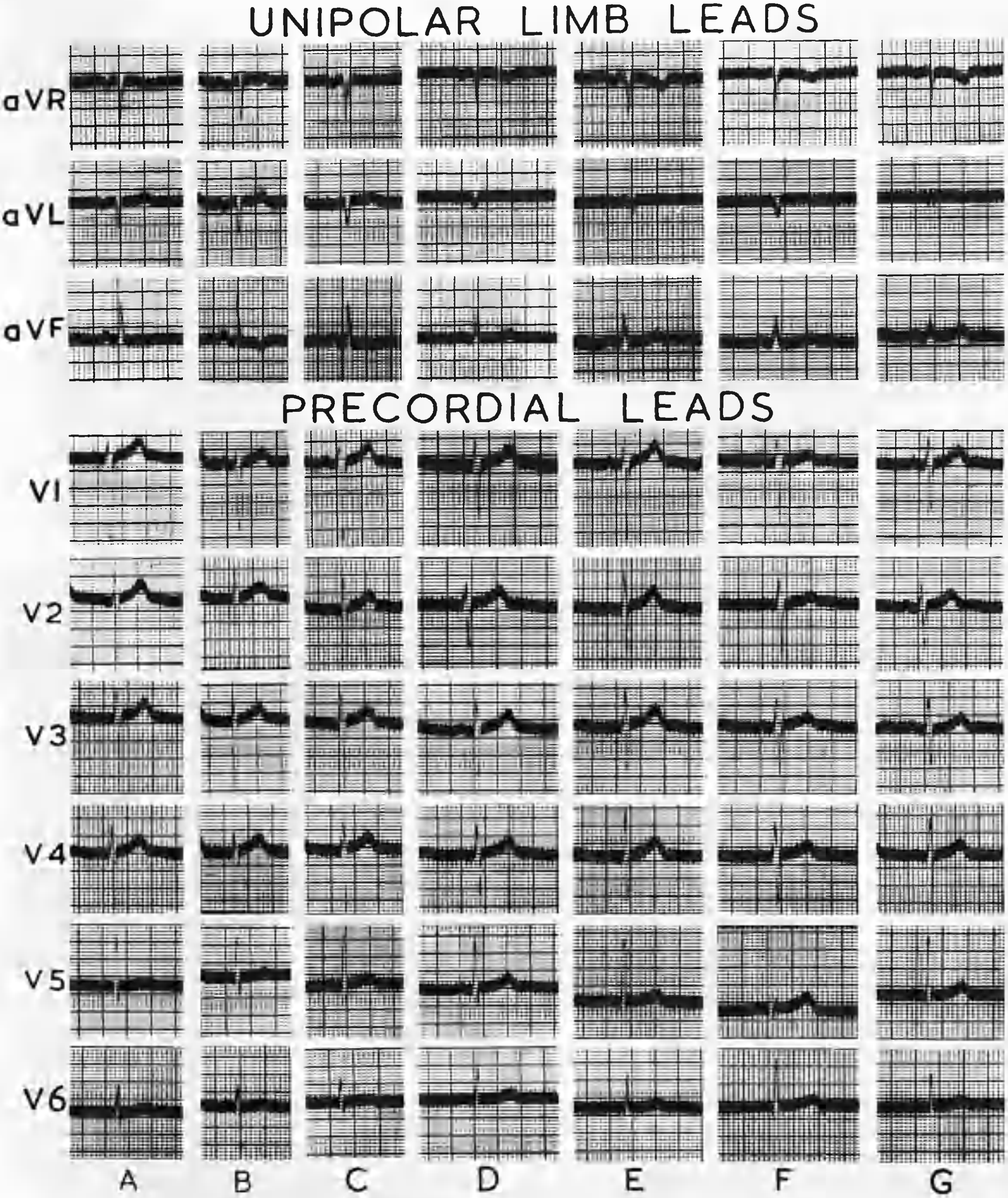
Lead I shows increase in R and T.
Lead II shows increase in R and T.
Lead III shows decrease in R and increase in T.
There has been a shift of the QRS axis to the left.

F: Left Lateral.

Lead I shows slight increase in s.
Lead II shows slight decrease in R.
Lead III shows slight decrease in R and T.

G: Prone.

Lead I shows increase in R and T.
Lead II shows decrease in R and increase in T.
Lead III has a small vibratory rsr's'r'' pattern; T is slightly decreased.
There has been a shift of the QRS axis to the left.



UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

CASE NO.32 (contd.)

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.

aVL has slightly inverted P and flat T waves and a qrs pattern.

aVF has upright P and T waves and an R pattern.

The heart is probably horizontal.

Vertical Rotation.

A: Sitting.

aVR shows a deeper QS and less inverted T.

aVL has a QS pattern; P is more inverted and T is upright.

aVF shows an increased R pattern; P is increased and T is flat.

The heart has probably become more vertical.

B: Standing.

aVR has an rS pattern; P is more deeply inverted; the ST interval is slightly elevated and T is upright.

aVL has a deep QS pattern; P is more inverted and T is upright.

aVF has a qR pattern with increase in R; P is increased; the ST interval is depressed and T is inverted.

The heart has become vertical.

C: 45° head up.

The changes are similar to those in B but are less in degree.

Horizontal Rotation.

E: Right Lateral.

aVR shows a deeper QS; P and T are more deeply inverted.

aVL shows a slightly bigger qrS pattern.

aVF shows slight increase in P,R and T.

F: Left Lateral.

aVL shows a small QS pattern.

G: Prone.

aVR shows a deeper QS; T is more inverted.

aVL has a qrs pattern; P and T are flat.

aVF shows decrease in R; T is increased.

The heart has become horizontal.

PRECORDIAL LEADS.

D: Supine.
V1 and V2 have rS patterns.
V3 and V4 have RS patterns.
V5 and V6 have qRs patterns.
P and T are upright in all leads.
There is moderate clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.
V1 to V4 have rS patterns with increase in S.
V5 and V6 have qRs patterns with increase in s.
There has been further clockwise rotation.

B: Standing.
V1 to V4 have rS patterns with reduction in r.
V5 and V6 have qRs patterns with increase in q and s and reduction in R.
There has been further clockwise rotation and the heart has become more vertical.

C: 45° head up.
V1 to V4 have rS patterns.
V5 has an Rs pattern with increase in s.
V6 has a qRs pattern with increase in s.
There has been clockwise rotation.

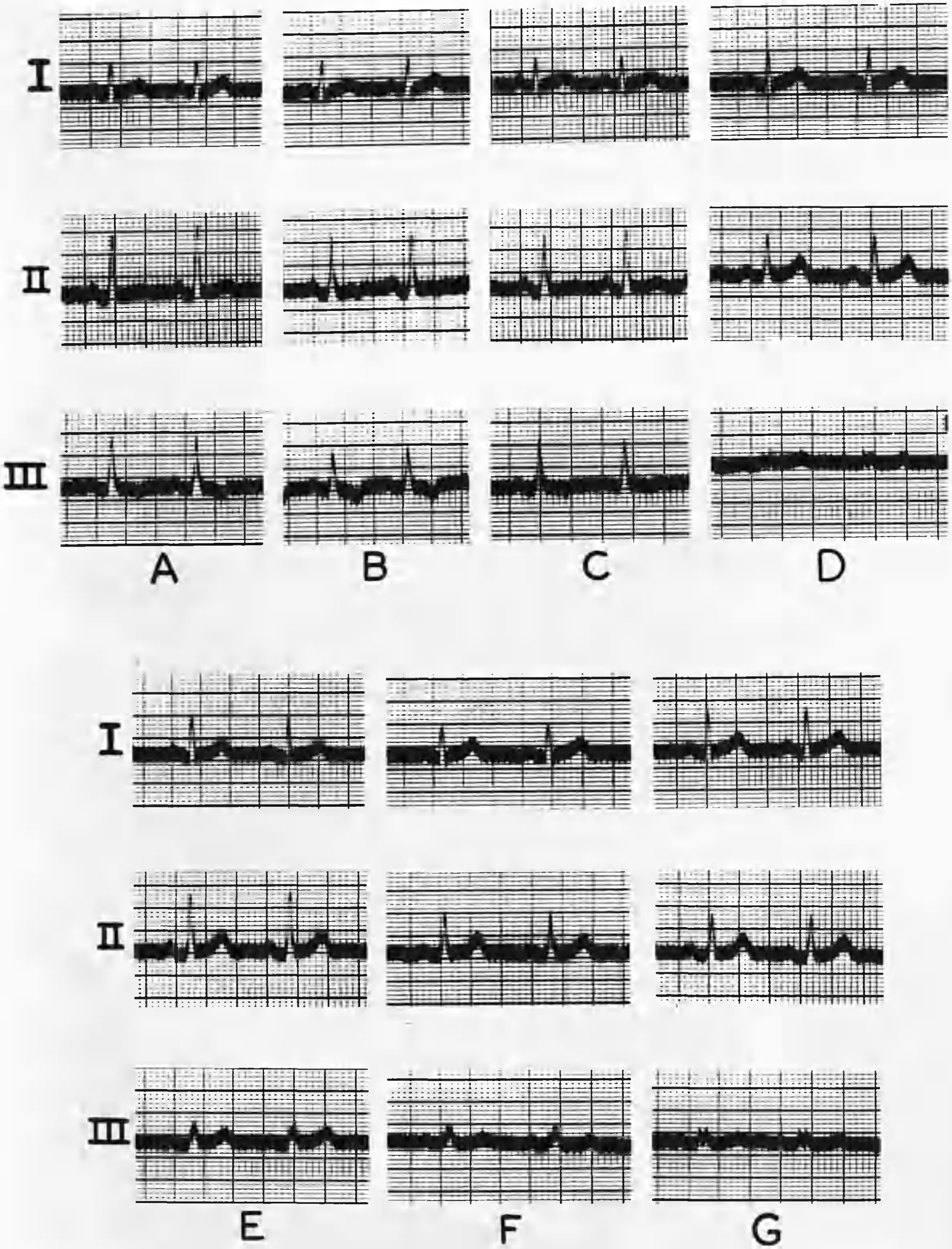
Horizontal Rotation.

E: Right Lateral.
V1 has an rS pattern with increase in r and S.
V2 to V4 have RS patterns with increase in R.
V5 has a qRs pattern with reduction in s.
V6 has a qR pattern.
T is increased in V1 to V4 and decreased in V5 and V6.
Displacement to the right has occurred.

F: Left Lateral.
V1 and V2 have rS patterns.
V3 and V4 have RS patterns.
V5 and V6 have qRsr' patterns with increase in q and R.
T is reduced in V1 to V4 and increased in V5 and V6.
Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.
V1 and V2 have rS patterns.
V3 and V4 have RS patterns with increase in R.
V5 has a qRs pattern ; V6 has a qR pattern.
Some counter-clockwise rotation has occurred.

STANDARD LIMB LEADS



NORMAL. A.R.

Age 18 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has a qRs pattern: lead II has an R pattern: lead III has a small vibratory rsr' pattern.
All leads have upright P and T waves.

Vertical Rotation.
A: Sitting.
Lead I shows reduction in q and R and increase in s: T is slightly reduced.
Lead II shows increase in R and decrease in T.
Lead III shows an R pattern; T is inverted.
There has been a shift of the QRS axis to the right.

B: Standing.
Lead I has an Rs pattern with increase in s; T is reduced.
Lead II shows increase in R; T is inverted and the RT interval is slightly depressed.
Lead III has an R pattern; T is deeply inverted.

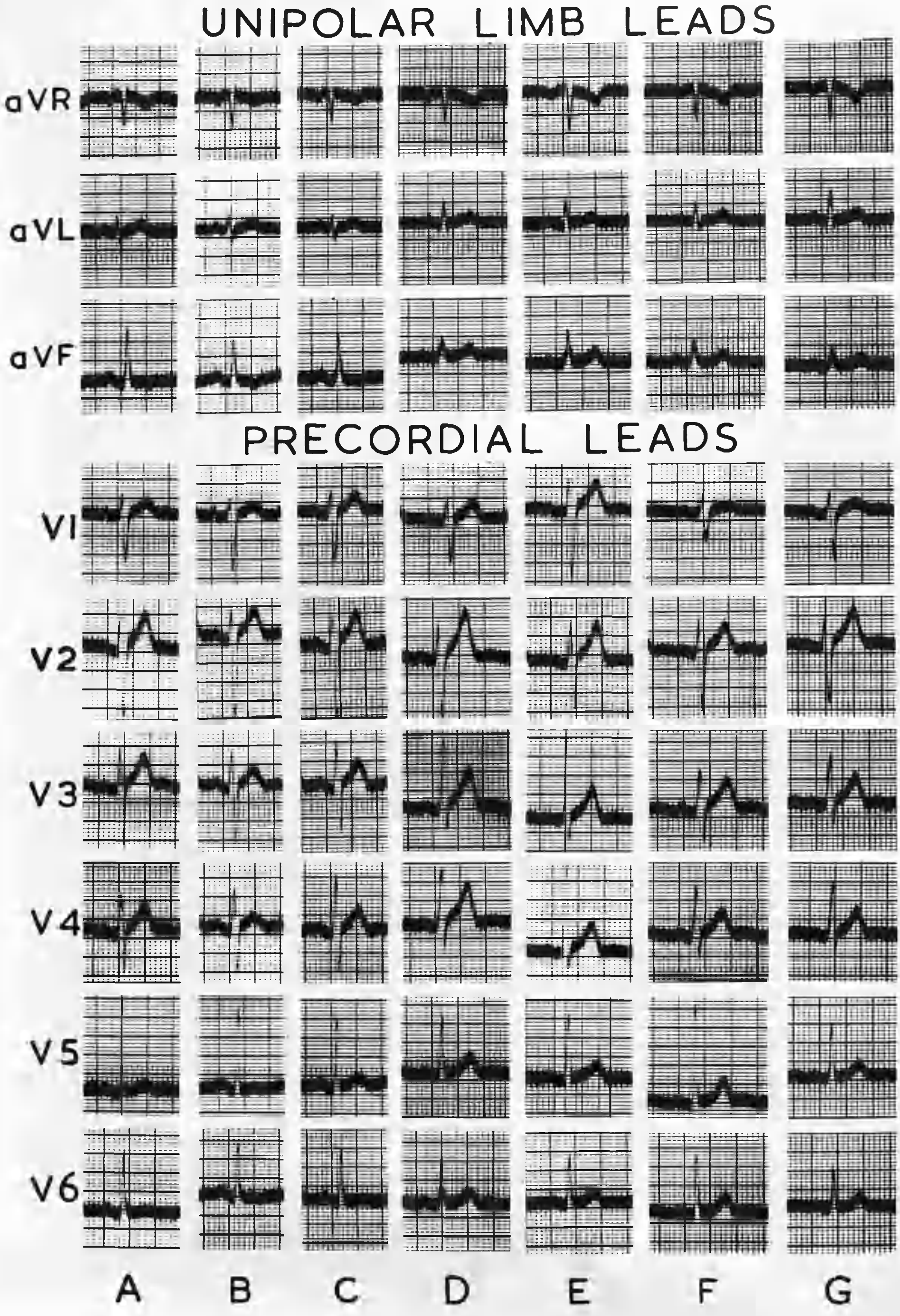
C: 45° head up.
Lead I shows an Rs pattern with decrease in R and increase in s; T is reduced.
Lead II has a qR pattern with increase in R; T is reduced.
Lead III has an R pattern; T is slightly inverted.

In A, B and C there has been a shift of the QRS axis to the right.

Horizontal Rotation.
E: Right Lateral.
Lead I shows increase in q and R and decrease in s.
Lead II shows increase in R.
Lead III has a small splintered R pattern.
T is increased in all leads.

F: Left Lateral.
Lead I shows decrease in R: lead III shows a small splintered R pattern.

G: Prone.
Lead I shows increase in q, R and T: lead III has a small vibratory rsr' pattern.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It probably faces the cavity of the right ventricle.

aVL has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

aVF has uoright P and T waves and a splintered R pattern.

It probably faces the epicardial surface of the right ventricle.

The heart is semi-horizontal.

Vertical Rotation.

A: Sitting.

aVR has a Qr pattern and less inverted T. It now faces the back of the heart.

aVL has an RS pattern. It now faces the epicardial surface of the right ventricle.

aVF has a qR pattern; T is slightly inverted. It now faces the epicardial surface of the left ventricle.

The heart has become vertical, and has undergone clockwise rotation.

B: Standing.

aVR has a Qr pattern with increase in Q; T is still less inverted.

aVL has an RS pattern and decrease in T.

aVF has a qR pattern; T is inverted.

The heart is vertical.

C: 45° head up.

The changes are intermediate between A and B.

Horizontal Rotation.

E: Right Lateral.

aVR has an rSr' pattern with increase in S; T is more deeply inverted.

aVL has a qRs pattern.

aVF has an increased R and T.

The heart has become slightly less horizontal.

F: Left Lateral.

aVL shows slight decrease in R and increase in s.

The heart is slightly less horizontal.

G: Prone.

aVL shows a qRs pattern with increase in q and R. T is increased.

The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI has an rS pattern.
V2 has an RS pattern.
V3,V4 and V5 have Rs patterns.
V6 has a qR pattern.
T is upright in all leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns.

V3 and V4 have RS patterns, with reduction in R.

V5 has a qRs pattern and V6 has a qR pattern with increase in R.

There has been clockwise rotation and the heart has become more vertical.

B: Standing.

The patterns are similar to those in A but T is considerably reduced in all leads and is slightly inverted in V5 and V6.

C: 45^{o} head up.

The patterns are similar to those in A.

In A,B and C there has been clockwise rotation along with a more vertical position of the heart.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S; T is increased.

V2 has an RS pattern; T is reduced.

V3 and V4 have Rs patterns with increase in R; T is reduced.

V5 has an Rs pattern and V6 an R pattern.

Some displacement to the right has occurred with possible slight clockwise rotation.

F: Left Lateral.

VI shows an rS pattern with reduction in r and S; T is reduced.

V2 and V3 have RS patterns with reduction in R; T is reduced.

V4 has an Rs pattern; T is reduced.

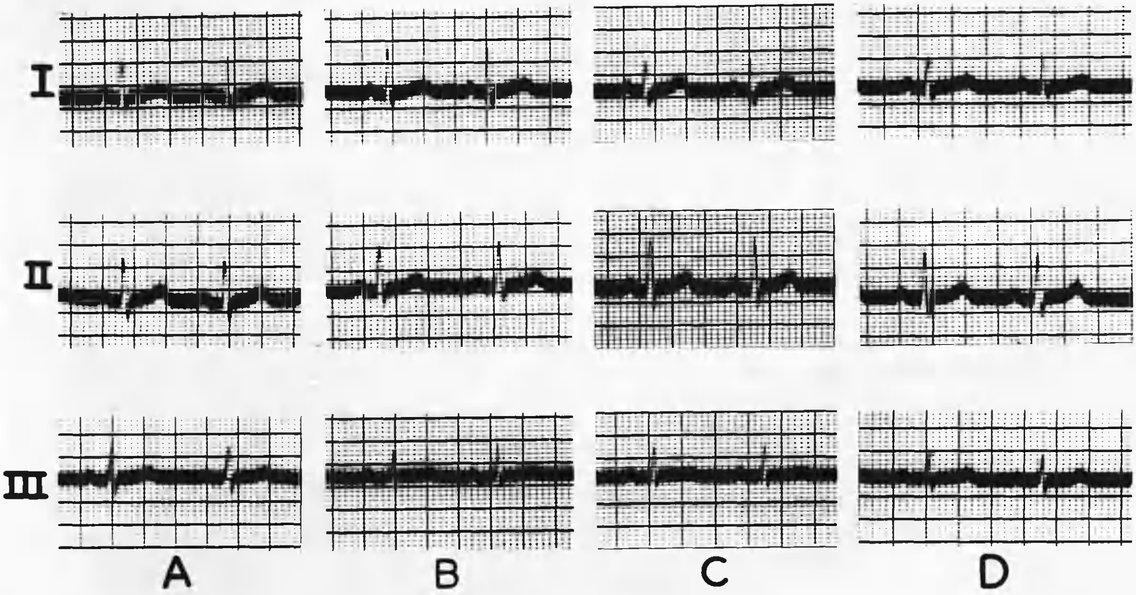
V5 and V6 have qR patterns with increase in R; T is increased.

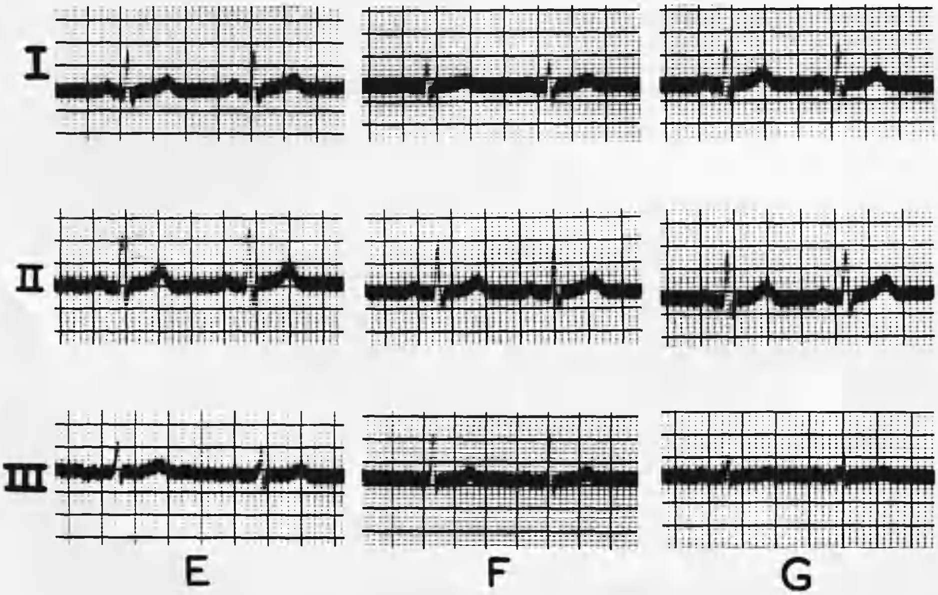
Displacement to the left has occurred along with counter-clockwise rotation.

G: Prone.

The patterns are similar to the control(D).

STANDARD LIMB LEADS





CASE NO. 34 PLATE I64a

NORMAL. W.R.

Age I5 years.

STANDARD LIMB LEADS.

D: Supine.

All leads have upright P and T waves.
Lead I has a qRs pattern.
Leads II and III have Rs patterns.

Vertical Rotation.

A: Sitting.

The patterns remain similar to the control but R and s are increased in leads I and III; T is flattened in leads II and III.

B: Standing.

R and s are increased in lead I; R is increased and s reduced in lead III; T is flattened in leads II and III.

C: 45° head up.

Lead I shows increase in s; lead III shows increase in R and decrease in s; T is increased in lead I and reduced in lead III.

Horizontal Rotation.

E: Right Lateral.

Leads I and II show increase in R and s; lead III shows increase in s; T is increased in all.

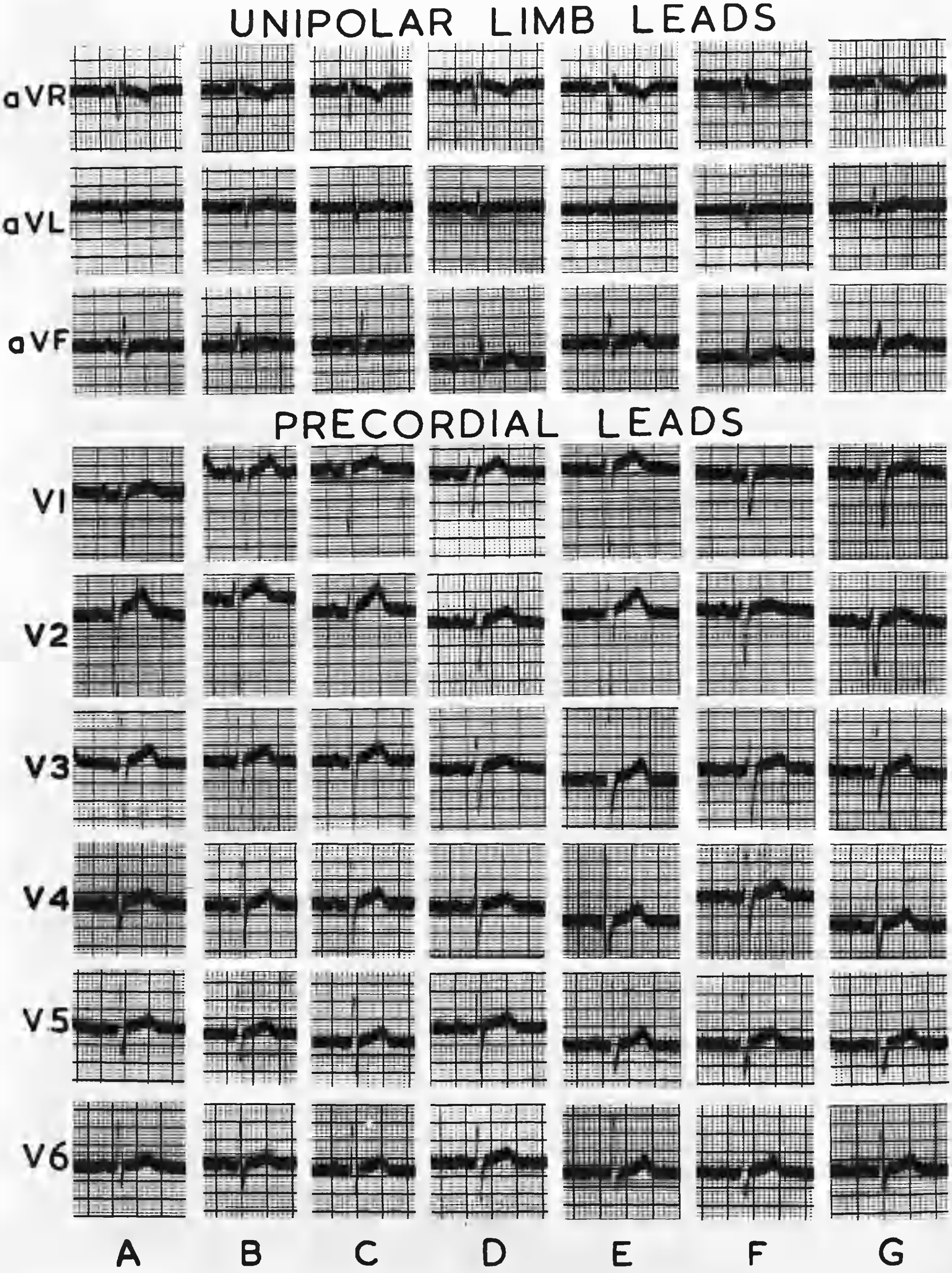
F: Left Lateral.

Lead I shows reduction in R and increase in s; lead III shows increase in R.

There has been a shift of the QRS axis to the right.

G: Prone.

Lead I shows increase in R and s; lead III shows decrease in R and s; T is increased in leads I and II and decreased in lead III.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It faces the cavity of the right ventricle.

aVL has upright P and low upright T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

aVF has upright P and T waves and an Rs pattern. It faces the epicardial surface of the right ventricle.

The heart is horizontal.

Vertical Rotation.

A: Sitting.

aVL has upright P and T waves and an rSr' pattern.

aVF has upright P and low upright T waves and a qRs pattern.

The heart has become vertical.

B: Standing.

aVL has an rS pattern.

aVF has an Rs pattern.

The heart is vertical with backward rotation of the apex.

C: 45° head up.

aVL has an rS pattern.

aVF has a qRs pattern and diphasic T wave.

The heart is vertical with forward rotation of the apex.

Horizontal Rotation.

E: Right Lateral.

aVL has a qRs pattern.

aVF has an Rs pattern.

The heart is horizontal with backward rotation of the apex.

F: Left Lateral.

aVL has a qrS pattern.

aVF has an Rs pattern with increase in R.

The heart is less horizontal.

G: Prone.

aVL has a qRs pattern with increase in R and T is increased.

The heart is more horizontal.

PRECORDIAL LEADS.

D: Supine.
Leads VI and V2 have rS patterns.
Leads V3 to V6 have RS patterns.
All have upright P and T waves.
There is marked clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.
Leads VI and V2 have rS patterns with increase in S.
Lead V3 has an RS pattern with increase in R and S.
Leads V4 to V6 have Rs patterns with increase in R.
There has been counter-clockwise rotation of the heart.

B: Standing.
The Rs pattern commences in V5.
Counter-clockwise rotation of less degree than in A has occurred.

C: 45^{o} head up.
The Rs pattern commences in V6.
Counter-clockwise rotation of less degree than in B has occurred.

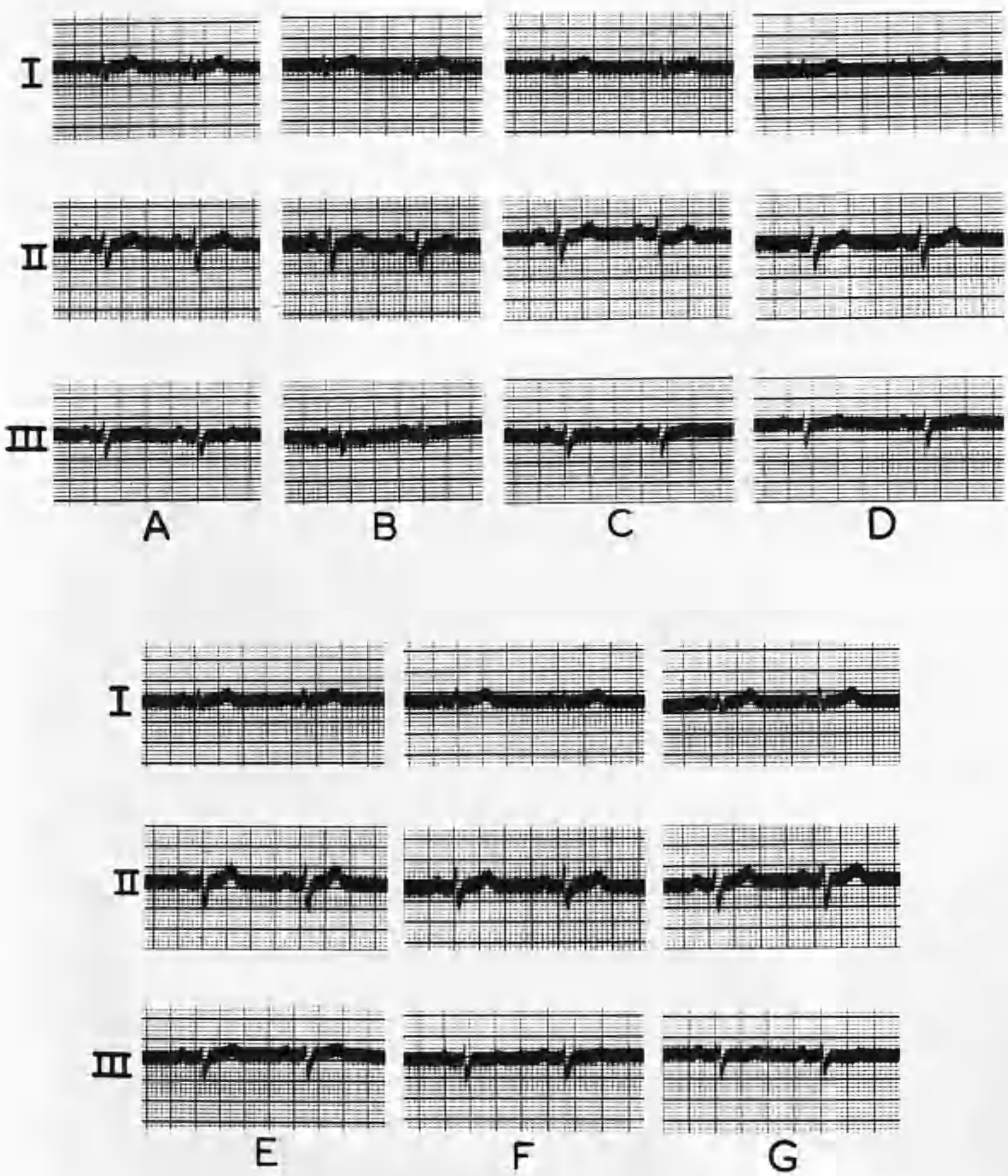
Horizontal Rotation.

E: Right Lateral.
VI and V2 have rS patterns with increase in S.
V3 and V4 have Rs patterns.
V5 and V6 have qRs patterns.
T is increased in all.
Some displacement to the right has occurred along with counter-clockwise rotation.

F: Left Lateral.
VI to V4 are similar to the control but T is reduced in VI and V2.
V5 and V6 have Rs patterns.
Some displacement to the left has occurred along with counter-clockwise rotation.

G: Prone.
V3 and V4 have RS patterns.
V5 and V6 have Rs patterns.
Some counter-clockwise rotation has occurred.

STANDARD LIMB LEADS



NORMAL. **W.A.**

Age 33 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has a small Rs pattern.
Lead II has an RS pattern.
Lead III has an rS pattern.
P and T are upright in all leads.

Vertical Rotation.

A: Sitting.
Lead I has an RS pattern; T is increased.
Lead II shows increase in P and decrease in T.
Lead III shows increase in P and decrease in S; T is slightly diphasic.

B: Standing.
Lead I has an RS pattern.
Lead II shows increase in P and decrease in T.
Lead III has an RS pattern with decrease in S; P is increased; T is inverted.
There has been a shift of the QRS axis to the right.

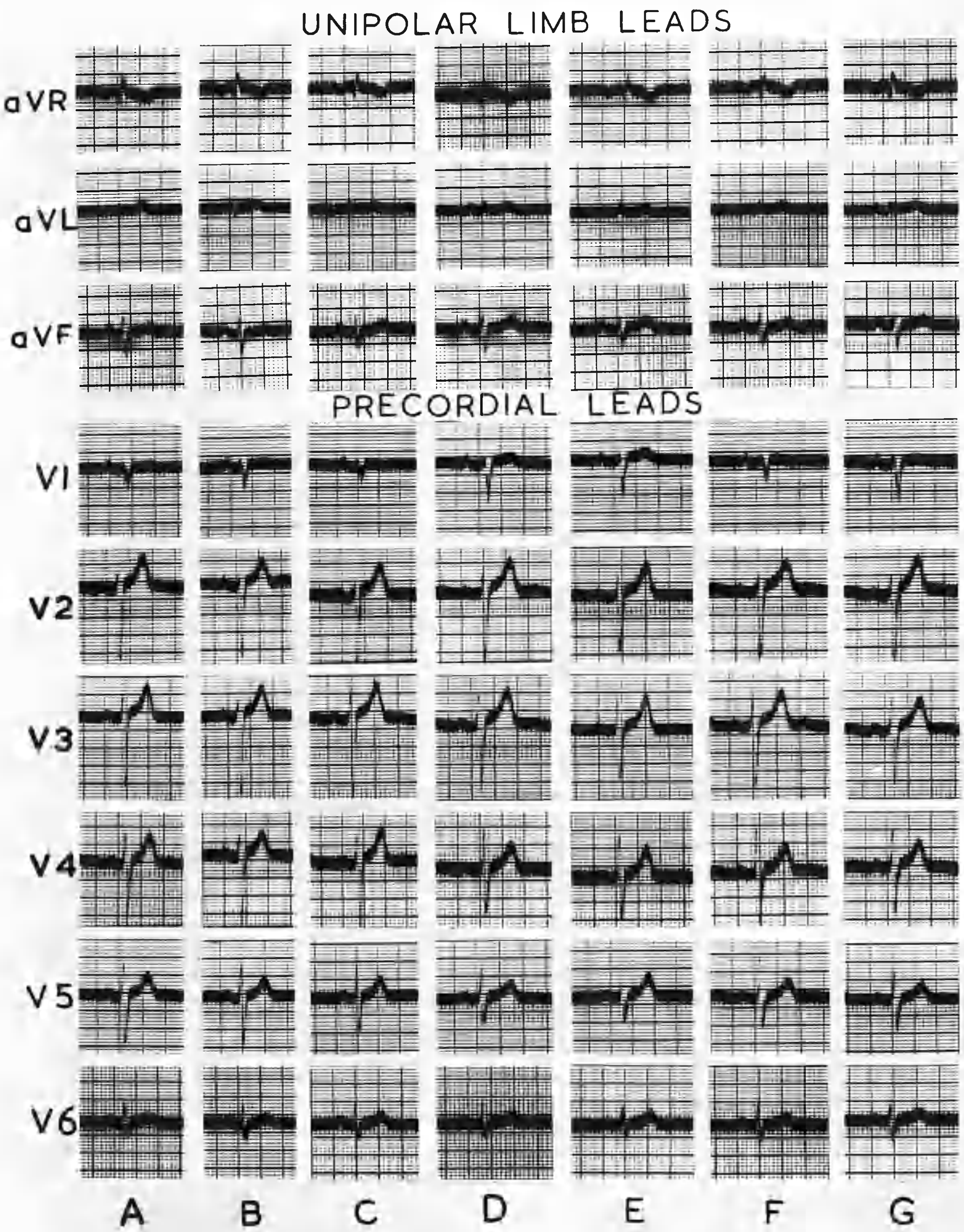
C: 45° head up.
Lead I has an Rs pattern with increase in s.
Lead II shows slight reduction in S and T and increase in P.
Lead III shows increase in P and reduction in S and T.

Horizontal Rotation.

E: Right Lateral.
Lead I shows increase in T.
Lead II shows increase in T.
Lead III shows reduction in r and increase in T.
There has been a shift of the QRS axis to the left.

F: Left Lateral.
The patterns show no change from the control series.

G: Prone.
Lead I shows increase in R,s and T.
Lead II shows increase in S and T.
Lead III shows decrease in r and increase in S; T is slightly diphasic.
There has been a shift of the QRS axis to the left.



UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and a QR pattern. It faces the back of the heart.

aVL has upright P and T waves and a small splintered qr pattern. It tends to face the epicardial surface of the left ventricle.

aVF has upright P and T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

The heart is semi-horizontal.

Vertical Rotation.

A: Sitting.

aVR shows increase in R.

aVL has a small splintered rsr's' pattern; P is slightly inverted; T is increased.

aVF shows increase in P and decrease in T.

The heart has become less horizontal.

B: Standing.

aVR shows reduction in Q and increase in R; T is less inverted.

aVL shows a small splintered rs pattern; P is diphasic.

aVF shows a qRS pattern; P is increased and T is reduced.

The heart has become vertical.

C: 45° head up.

The changes are intermediate between those in A and B.

Horizontal Rotation.

E: Right Lateral.

aVR shows increase in R; P and T are more deeply inverted.

aVL shows a small splintered qR pattern.

aVF shows an rS pattern; T is increased.

The heart has become more horizontal.

F: Left Lateral.

The patterns are similar to the control series but aVF shows reduction in S and T.

G: Prone.

aVL shows increase in T.

aVF shows an rS pattern; T is reduced.

The heart has become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 and V5 have RS patterns.
V6 has an Rs pattern.
P and T are upright in all leads.
There is marked clockwise rotation of the heart.

Vertical Rotation.

A: Sitting.

VI to V4 have rS patterns with reduction of S in VI and V2.

V5 has an RS pattern with increase in S.

V6 has an Rs pattern.

There has been further clockwise rotation.

B: Standing.

VI to V5 have rS patterns with reduction of S in VI and V2 and increase of S in V3 to V5.

V6 has a qRS pattern.

T is reduced in all leads.

There has been further clockwise rotation of the heart, and it has become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree except in VI where S is smaller and T is slightly inverted.

Horizontal Rotation.

E: Right Lateral.

The patterns are similar to the control series but T is increased in VI; S is decreased in V2 and V3; R is decreased in V6.

Slight displacement to the right has occurred.

F: Left Lateral.

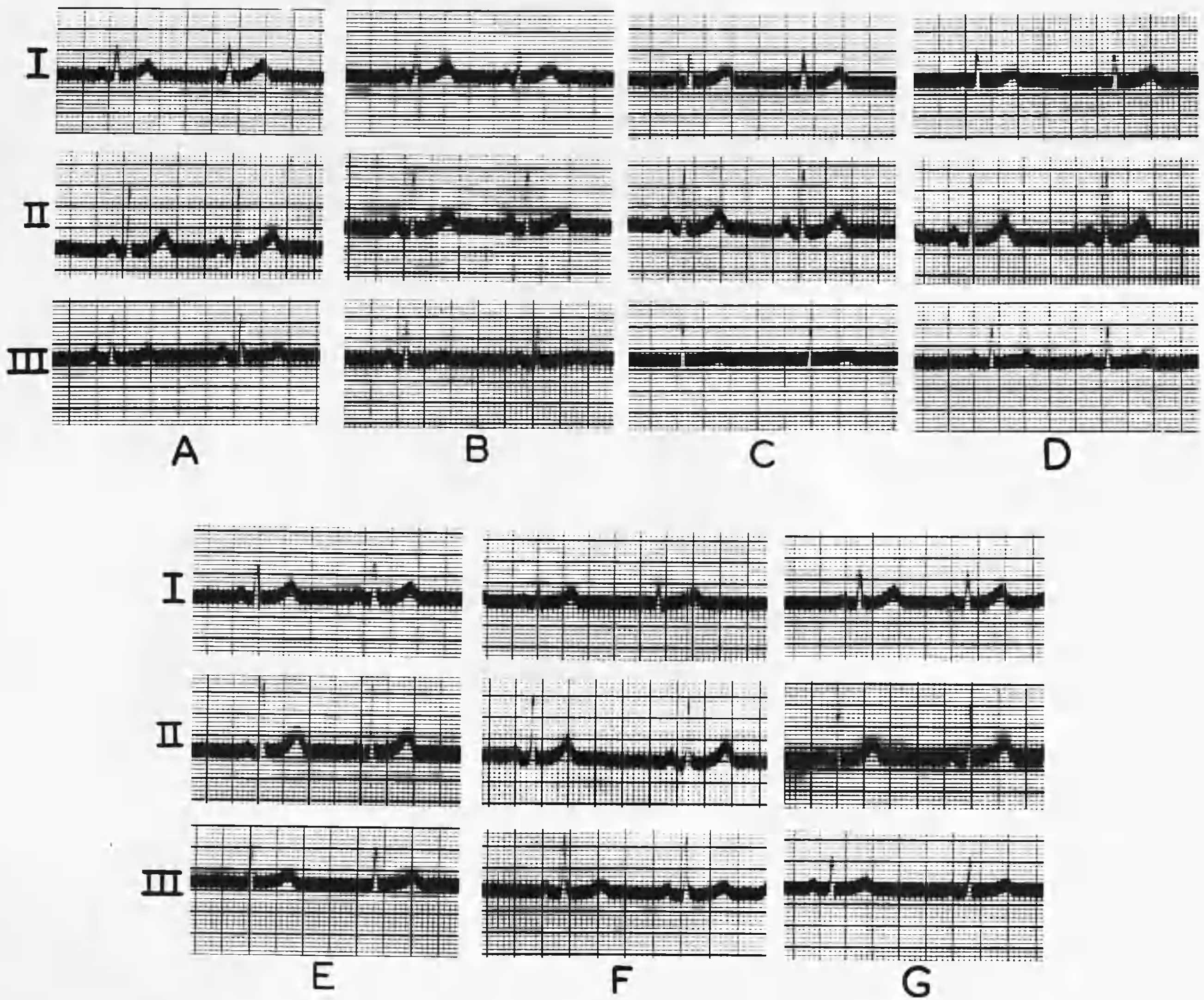
The patterns are similar to the control series but in VI S is reduced and T is slightly inverted; r is reduced in V2; R is increased in V5 and V6.

Some displacement to the left has occurred.

G: Prone.

VI has a QS pattern and T is reduced.
V2 to V5 resemble the control series.
V6 has an RS pattern.
The heart has become more horizontal.

STANDARD LIMB LEADS



NORMAL.

Miss M.H.

Age I7 years.

STANDARD LIMB LEADS.

D: Supine.
All leads have upright P and T waves and R patterns. There is no axis deviation.

Vertical Rotation.
A: Sitting.
Lead I has an Rs pattern.
Lead III shows increase in R.
The QRS axis has shifted slightly to the right.

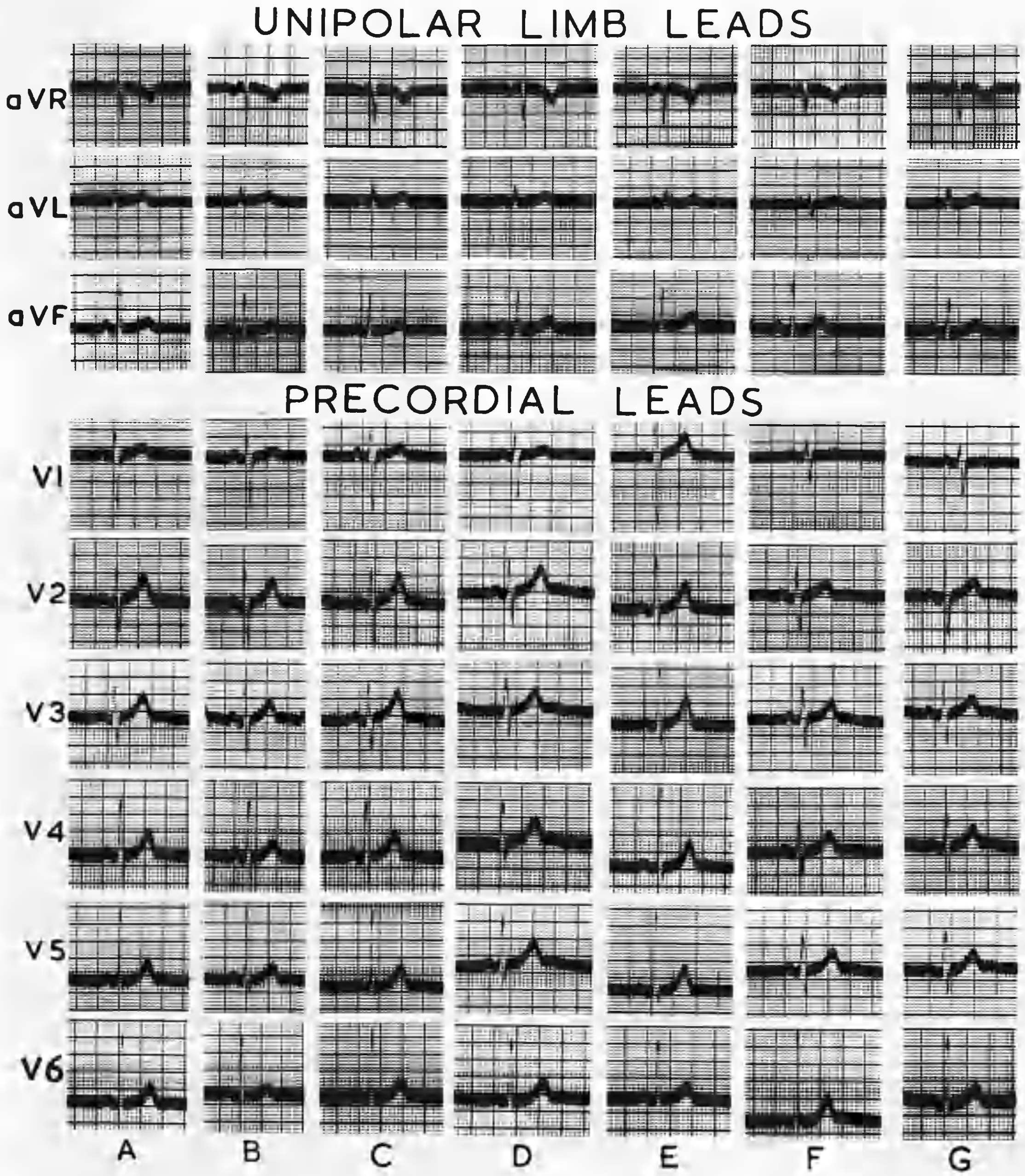
B: Standing.
Lead I has an Rs pattern.
Lead II shows decrease in R and T.
Lead III shows a qR pattern with increase in R; T is practically flat.
There has been a shift of the QRS axis to the right.

C: 45^{o} head up.
Lead I has an Rs pattern.
Lead II shows slight decrease in T.
Lead III shows increase in R.
There has been a shift of the QRS axis to the right.

Horizontal Rotation.
E: Right Lateral.
Lead I shows increase in P, R and T.
Lead II shows increase in T.
Lead III has an Rs pattern; P is reduced and T is increased.
There has been a shift of the QRS axis to the left.

F: Left Lateral.
Lead I has an Rs pattern with reduction in R.
Lead III has a qR pattern with increase in R; T is increased.
There has been a shift of the QRS axis to the right.

G: Prone.
Lead I shows increase in R and T.
Lead II shows decrease in R.
Lead III has an Rs pattern with decrease in R; T is slightly increased.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

CASE NO. 36 (contd.) PLATE 166b

UNIPOLAR LIMB LEADS.

D: Supine.
aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.
aVL has upright P and T waves and an R pattern.
aVF has upright P and T waves and a taller R pattern.
The heart is in the intermediate position.

Vertical Rotation.
A: Sitting.
The patterns are similar to the control series but R is slightly decreased in aVL and increased in aVF.

B: Standing.
The patterns are similar to the control but QS is slightly deeper in aVR and R is slightly reduced in aVL; T is decreased in aVF.

C: 45° head up.
The patterns are similar to the control but QS is slightly deeper in aVR and R is slightly decreased in aVL; T is slightly reduced in aVF.

In A, B and C there has been no significant change in the position of the heart.

Horizontal Rotation.
E: Right Lateral.
aVR has a deeper QS and more deeply inverted P and T.
aVL shows reduction in R and T.
aVF shows increase in T.

F: Left Lateral.
aVR has a smaller QS and less inverted P and T.
aVL has an rS pattern; T is reduced. It now faces the epicardial surface of the right ventricle.
aVF shows increase in R.
The heart is vertical with forward rotation of the apex.

G: Prone.
aVR shows a deeper QS and more inverted P and T.
aVL has an R pattern.
aVF has an Rs pattern with decrease in R; T is decreased.
The heart has probably become more horizontal.

PRECORDIAL LEADS.

D: Supine.

VI has an rS pattern.
V2 and V3 have RS patterns.
V4 to V6 have Rs patterns.
P and T are upright in all leads.
There is marked clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control series but R is slightly increased and s slightly decreased in V5 and V6.

There may have been some forward rotation of the apex.

B: Standing.

The patterns are similar to the control, but R is increased in V4 and V5 and s reduced in V5; T is reduced in V4 to V6.

The heart may have become slightly more vertical.

C: 45° head up.

The patterns are similar to those in B but the reduction in T is less.

Horizontal Rotation.

E: Right Lateral.

VI has an increased rS pattern; T is increased.
V2 to V5 have Rs patterns with increase in R.
V6 has an R pattern.
Some displacement to the right has occurred.

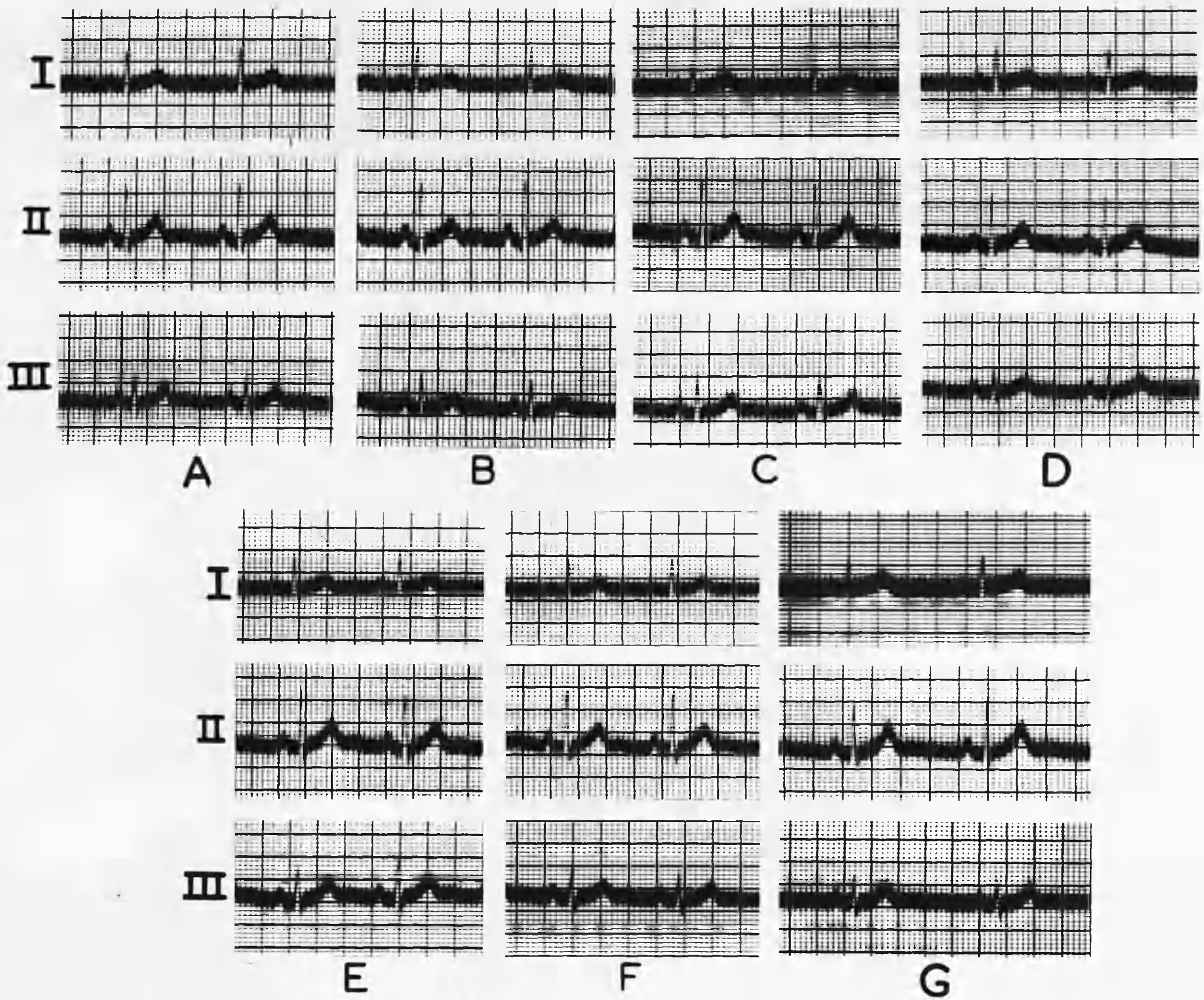
F: Left Lateral.

VI has a reduced rS pattern; T is reduced.
V2 to V4 have RS patterns.
V5 has an Rs pattern.
V6 has a qR pattern with increase in R; T is increased.
Displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

VI shows reduction in r,S and T.
V2 to V4 have RS patterns.
V5 and V6 have Rs patterns with decrease of R in V5 and increase of R in V6.
The heart may have become slightly more horizontal.

STANDARD LIMB LEADS



ABNORMAL. J.W.

Diagnosis: Neurocirculatory Asthenia. Age 33 years.

STANDARD LIMB LEADS.

D: Supine.
All leads have upright P and T waves and qRs patterns.

Vertical Rotation.

A: Sitting.
Lead I shows increase in s.
Lead II shows increase in R and s.
Lead III shows increase in R.
P is increased in leads II and III.

B: Standing.
Lead I shows increase in s and reduction in T.
Lead II shows increase in R.
Lead III shows increase in R.
P is increased and T is reduced in leads II and III.

C: 45° head up.
Lead I shows reduction in R.
Lead II shows increase in R.
Lead III shows increase in R.
P is increased in leads II and III.

In A,B and C there has been a shift of the QRS axis to the right.

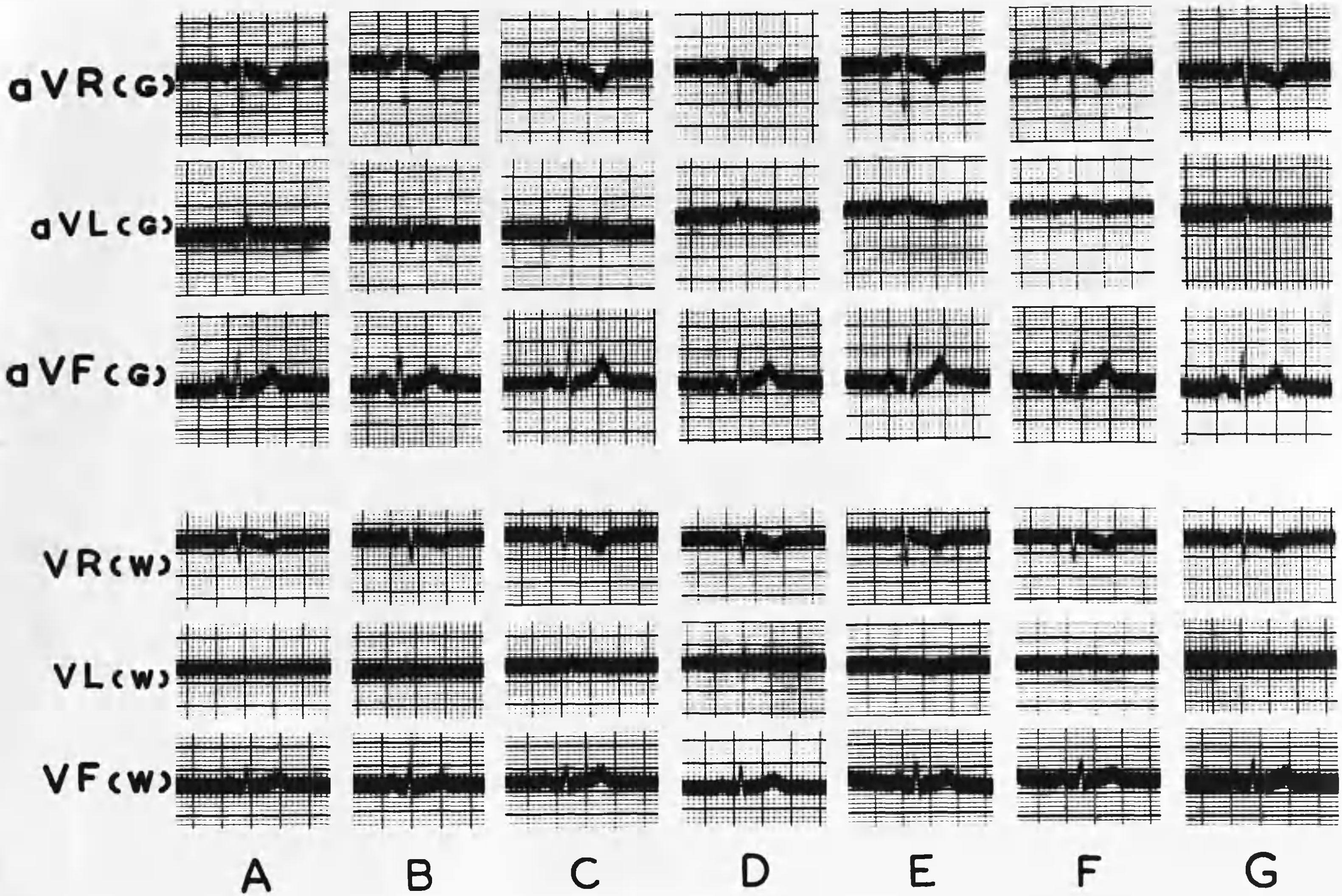
Horizontal Rotation.

E: Right Lateral.
Lead I has a qR pattern.
Lead II shows increase in s and T.
Lead III shows increase in R,s and T.
There has been a shift of the QRS axis to the left.

F: Left Lateral.
Lead I shows reduction in R.
Lead II shows increase in R and s.
Lead III shows increase in R and s.

G: Prone.
Lead I shows increase in T.
Lead II shows reduction in R and increase in s; T is increased.
Lead III shows increase in s; T is increased.
There has been a shift of the QRS axis to the left.

UNIPOLAR LIMB LEADS



UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rSr' pattern. It faces the epicardial surface of the right ventricle.

aVL has shallow inverted P and T waves and an Rsr' pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical with forward rotation of the apex.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control.

B: Standing.

aVL has an RSr' pattern with decrease in R.

The heart has become more vertical.

C: 45° head up.

The patterns are similar to the control.

Horizontal Rotation.

E: Right Lateral.

aVR has an rSr' pattern with increase in S and r'; P and T are more inverted.

aVL has an rsr' pattern; P and T are more inverted.

aVF shows increase in R and s; P and T are increased.

F: Left Lateral.

aVR shows increase in r'.

aVL has an rsr' pattern.

G: Prone.

The patterns are similar to the control.

The unaugmented (W) leads have patterns similar to the augmented (G) leads but the details are difficult to determine.

PRECORDIAL LEADS.

D: Supine.

VI has an rS pattern.
V2 has an RS pattern.
V3 and V4 have Rs patterns.
V5 and V6 have qRs patterns.
P and T are upright in all leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns.
V3 has an RS pattern.
V4 has an Rs pattern with increase in s.
V5 and V6 have qRs patterns with increase in R and s.
T is decreased in all leads.
There has been some clockwise rotation.

B: Standing.

The patterns are similar to those in A but R and T are smaller in V6 and s is increased.

There has been clockwise rotation and the heart has become more vertical.

C: 45^{o} head up.

The patterns are similar to those in A.

Horizontal Rotation.

E: Right Lateral.

The patterns are similar to the control.

F: Left Lateral.

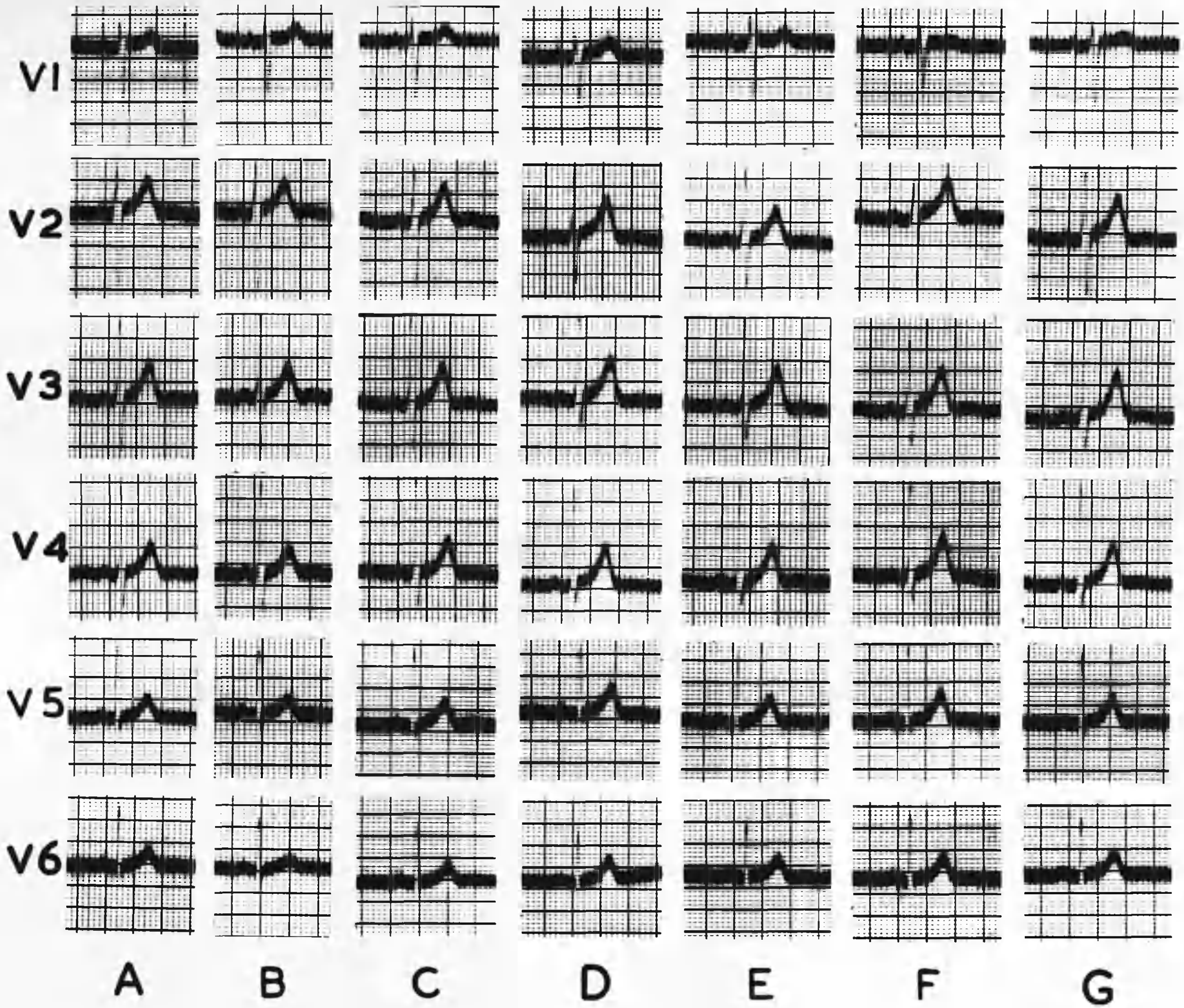
VI and V2 have rS patterns.
V3 has an Rs pattern with reduction in R and increase in s.
V4 has an Rs pattern.
V5 and V6 have qRs patterns with increase in R.
T is reduced in VI and increased in V4 to V6.
Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

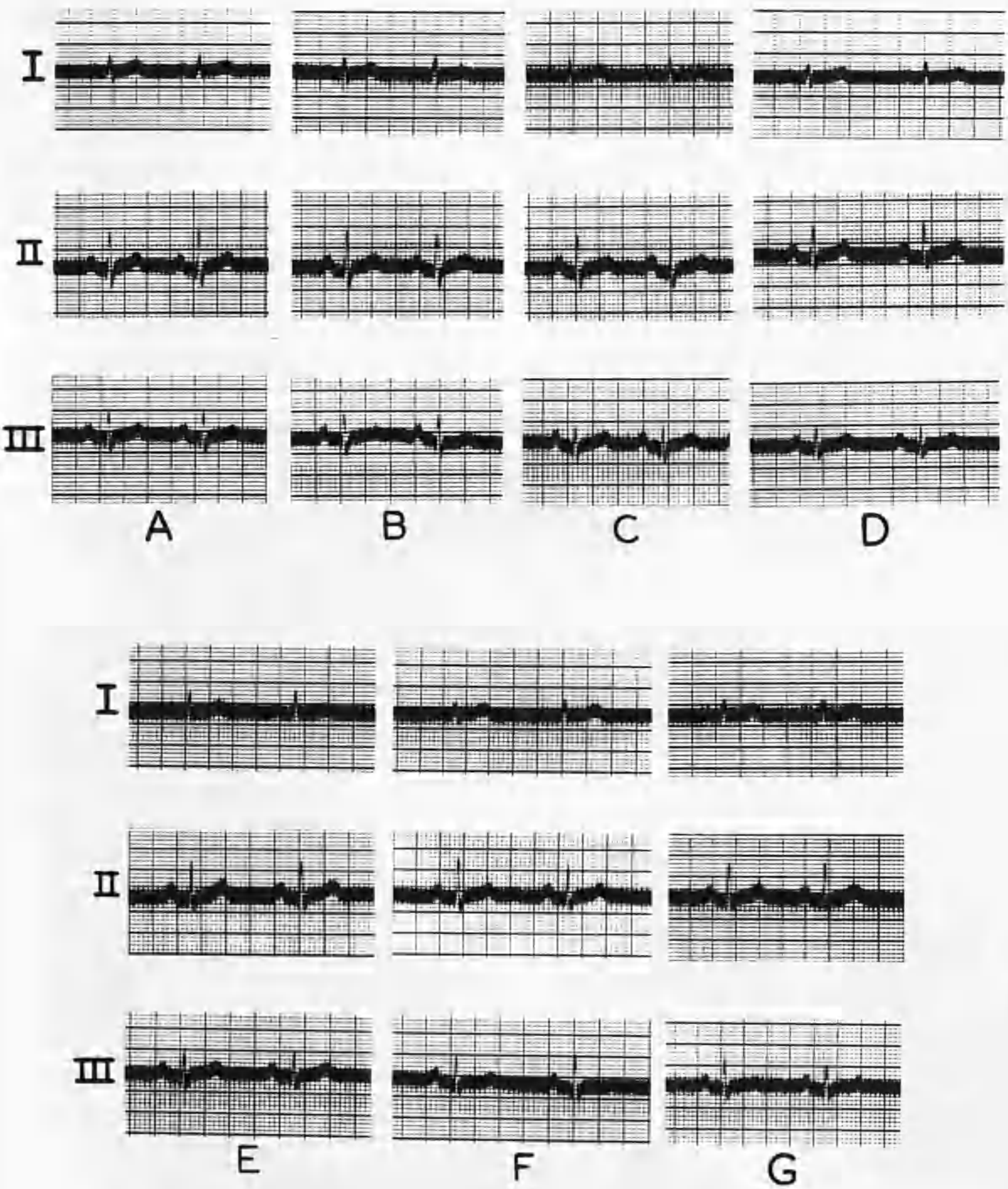
The patterns are similar to the control but in VI S is increased and T is reduced; in V5 and V6 R is increased.

There has been slight forward rotation of the apex.

PRECORDIAL LEADS



STANDARD LIMB LEADS



ABNORMAL. P.McK.

Diagnosis: Chronic Bronchitis and Emphysema. Age 49 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an Rs pattern.
Leads II and III have upright P and T waves and qRs patterns.

Vertical Rotation.

A: Sitting.

Lead I shows increase in R.
Lead II shows increase in R and s; T is slightly reduced.
Lead III shows increase in R and s.

B: Standing.

Lead I shows slight increase in R and s.
Lead II shows increase in R and s; T is reduced.
Lead III shows increase in P,R and s; T is reduced.

C: 45° head up.

The changes are similar to those in B but are of less degree.

In A,B and C there has been a shift of the QRS axis to the right.

Horizontal Rotation.

E: Right Lateral.

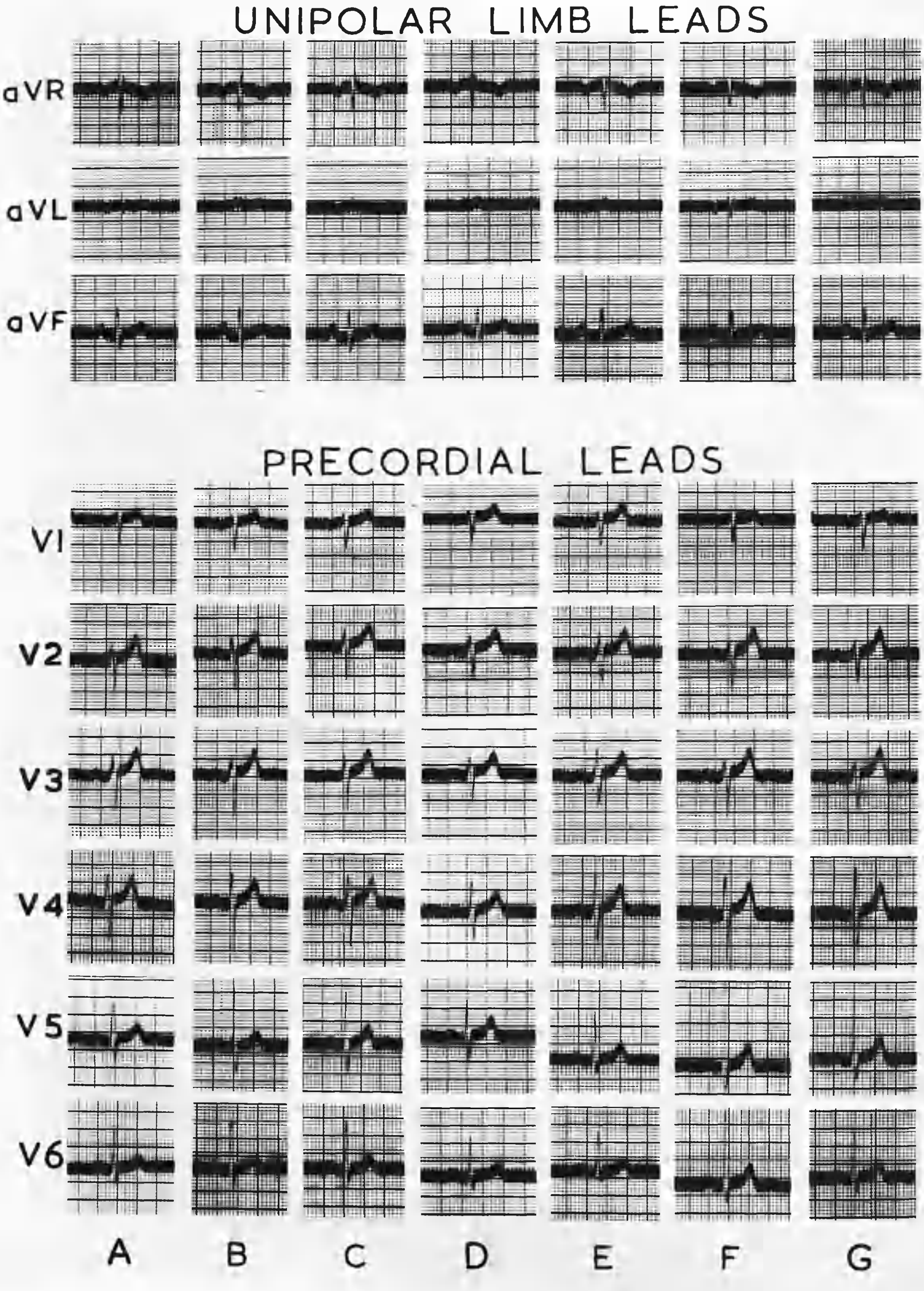
Lead I shows increase in R and reduction in s.
Lead II shows increase in R.
Lead III shows increase in R and s; T is increased.
There has been a shift of the QRS axis to the left.

F: Left Lateral.

Lead II shows increase in R; T is slightly reduced.
Lead III shows increase in R; T is reduced.
There has been a shift of the QRS axis to the right.

G: Prone.

Lead I shows an R pattern.
Lead II shows reduction in T.
Lead III shows reduction in T.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and a Qr pattern. It faces the back of the heart.

aVL has shallow inverted P and flat T waves and a small vibratory rsr' pattern. It probably faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and a qRs pattern. It faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.

A: Sitting.

aVL has an rsr' pattern; T is low upright.
aVF shows increase in R and s.
The heart has become more vertical.

B: Standing.

aVR shows increase in r; T is less inverted.
aVL has an rsr' pattern.
aVF shows increase in R and s; T is reduced.
The heart has become more vertical.

C: 45° head up.

The patterns are similar to those in B.

Horizontal Rotation.

E: Right Lateral.

aVR shows increase in Q; P and T are more inverted.
aVL has a small vibratory r pattern.
aVF shows increase in P and T.

F: Left Lateral.

aVL has an rsr' pattern; T is low upright.
aVF shows reduction in T.

G: Prone.

aVR shows increase in Q and reduction in r; T is more inverted.

aVL has an rs pattern; T is low upright.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 has an RS pattern.
V5 has an Rs pattern.
V6 has a qRs pattern.

P is diphasic in VI and upright and bifid in all other leads.

T is upright in all leads.

There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

The patterns are similar to the control series, but T is reduced in VI, V5 and V6.

B: Standing.

The patterns are similar to the control series but S is increased in VI to V4; R and s are increased in V5 and V6; T is reduced in VI and V5.

There has been a further clockwise rotation and the heart has become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

VI and V2 have rS patterns and T is increased.
V3 and V4 have RS patterns.
V5 has an Rs pattern with increase in R and reduction in s.
V6 has a qRs pattern with reduction in s.

Some displacement to the right has occurred.

F: Left Lateral.

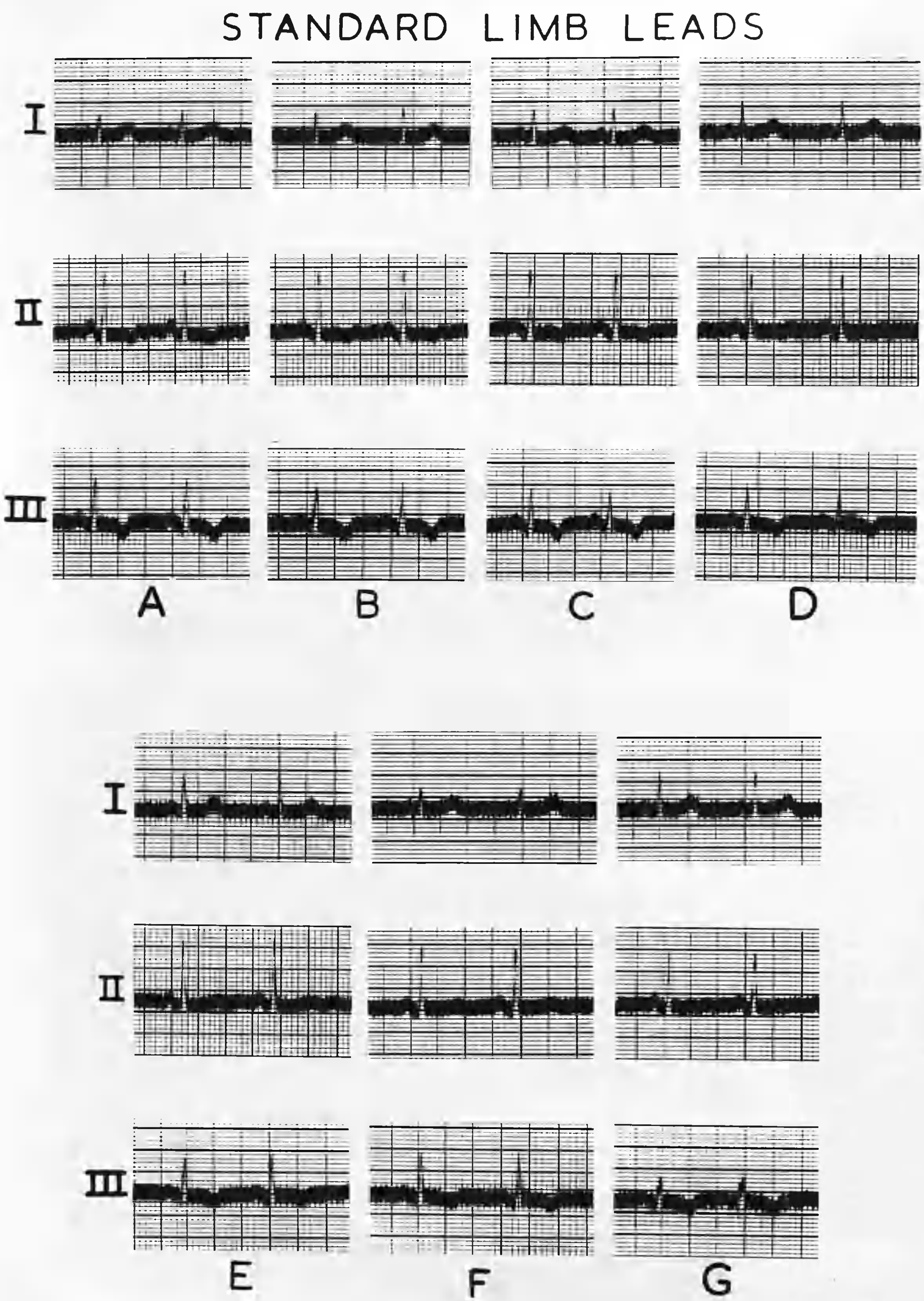
VI to V3 have rS patterns with increase in S in V2 and V3.
V4 has an RS pattern with increase in R and S.
V5 and V6 have qRs patterns with increase in R and s.

T is reduced in VI and increased in all other leads.

Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

VI to V3 have rS patterns with increase in S.
V4 has an RS pattern with increase in R and S.
V5 has an Rs and V6 has a qRs pattern with increase in R and s. T is reduced in VI and increased in all other leads. The heart has become more horizontal.


STANDARD LIMB LEADS
I
II
III
A
B
C
D
I
II
III
E
F
G

CASE NO.39 PLATE I69a

ABNORMAL. Mrs.M.McK.

Diagnosis: Essential Hypertension. Age 30 years.

STANDARD LIMB LEADS.

D: Supine.
Lead I has upright P and T waves and an R pattern.
Lead II has upright P and shallow diphasic T waves and a qR pattern.
Lead III has upright P and inverted T waves and a qR pattern.

Vertical Rotation.
A: Sitting.
Lead I has an Rs pattern with reduction in R.
Lead II shows increase in P,q and R; T is inverted.
Lead III shows increase in P,q and R; T is more deeply inverted.
There has been a shift of the QRS axis to the right.

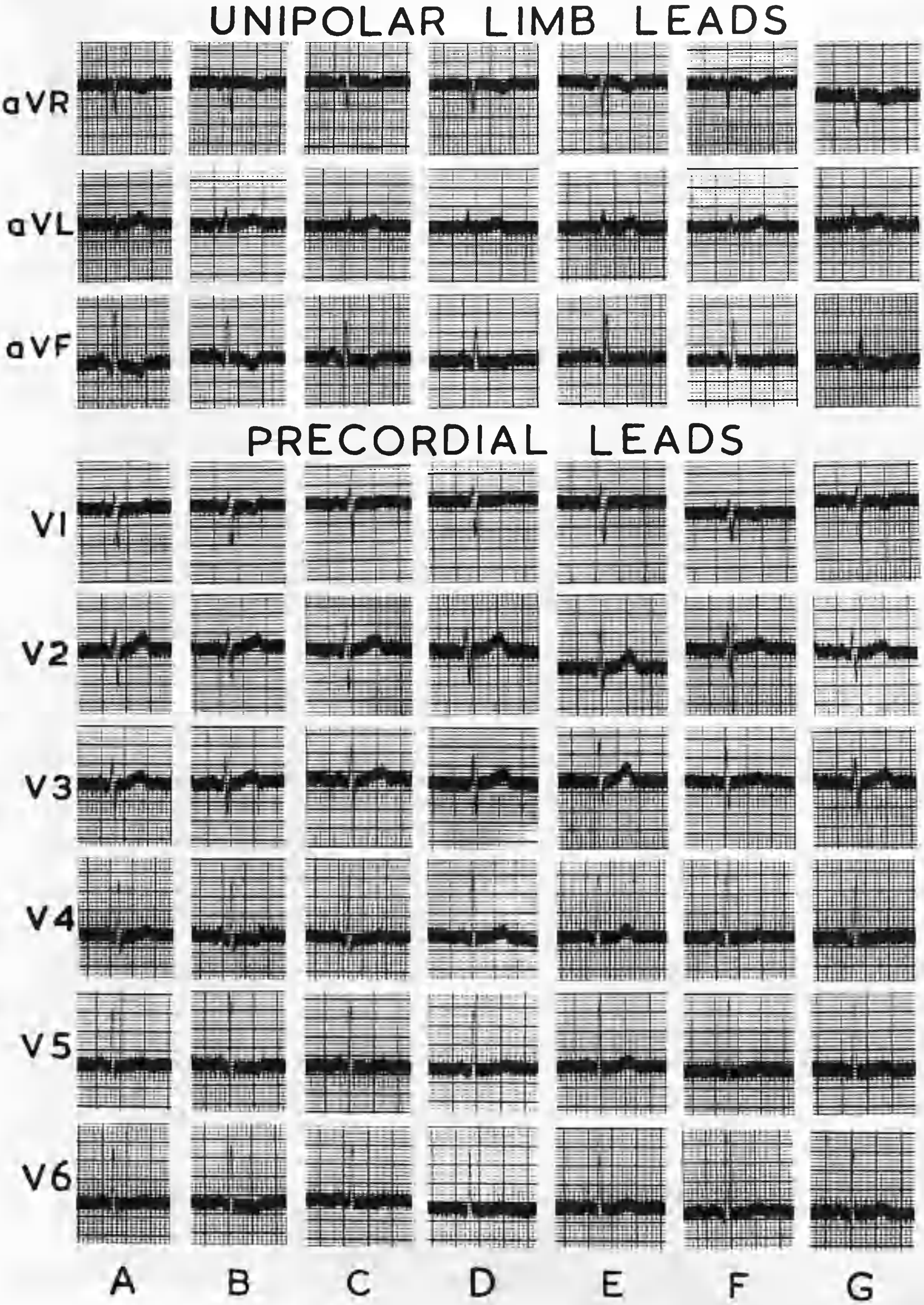
B: Standing.
The changes are similar to those in A.

C: 45° head up.
The changes are similar to those in A and B.

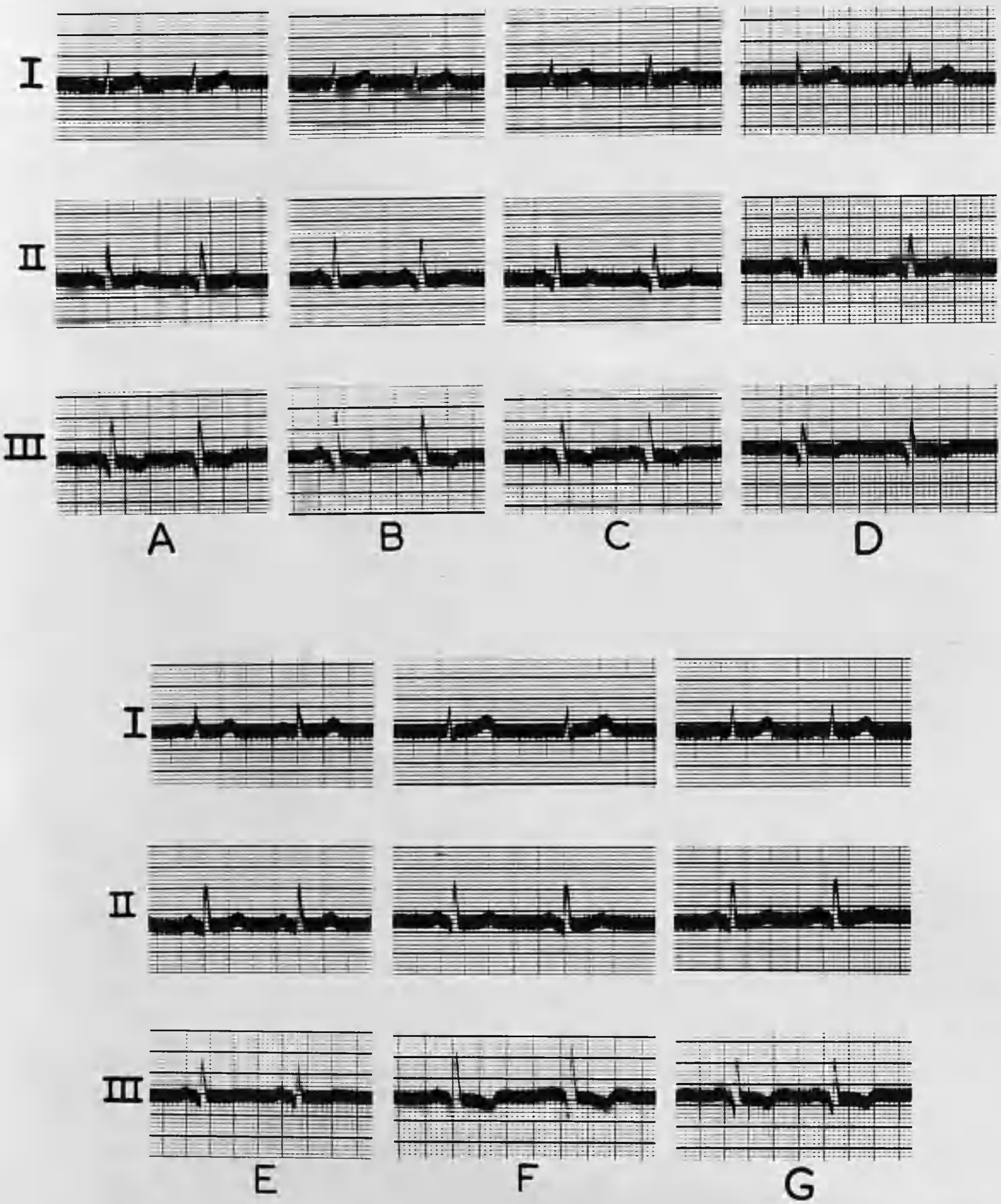
Horizontal Rotation.
E: Right Lateral.
Lead I shows increase in R.
Lead II shows increase in R; T is low upright.
Lead III shows a qRs pattern; T is less inverted.
There has been a shift of the QRS axis to the left.

F: Left Lateral.
Lead I shows reduction in R.
Lead II shows increase in R; T is low upright.
Lead III shows increase in R; T is less inverted.
There has been a shift of the QRS axis to the right.

G: Prone.
Lead I shows increase in R and T.
Lead II has flat T.
Lead III has a qRs pattern with reduction in R; T is more inverted.
There has been a shift of the QRS axis to the left.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

STANDARD LIMB LEADS



UNIPOLAR LIMB LEADS.

D: Supine.
aVR has inverted P and T waves and a QS pattern. It faces the cavity of the left ventricle.
aVL has upright P and T waves and an rsR' pattern. It probably faces the epicardial surface of the right ventricle.
aVF has upright P and shallow inverted T waves and a qR pattern. It faces the epicardial surface of the left ventricle.
The heart is vertical.

Vertical Rotation.
A: Sitting.
aVL has an rsr'S' pattern; T is increased.
aVF has a qR pattern with increase in q and R; P is increased and T is more deeply inverted.
The heart has become more vertical.

B: Standing.
aVR has less inverted T.
aVL has an Rs pattern; P and T are increased.
aVF has a qR pattern with increase in q and R;P is increased and T is more deeply inverted.
The heart has become more vertical.

C: 45° head up.
The changes are similar to those in B.

Horizontal Rotation.
E: Right Lateral.
aVR shows a deeper QS; P and T are more deeply inverted.
aVL has a splintered R pattern; T is increased.
aVF has a qR pattern with increase in R; T is flat.

F: Left Lateral.
aVL has an rsR's' pattern; T is increased.
aVF has a qR pattern with increase in q and R; T is slightly inverted.
There has probably been forward rotation of the apex.

G: Prone.
aVR shows a deeper QS.
aVL has a splintered R pattern; T is increased.
aVF has a qR pattern with reduction in q and R; T is more deeply inverted.
The heart has probably become less vertical, and there has been some forward rotation of the apex.

PRECORDIAL LEADS.

D: Supine.

VI has an rS pattern.
V2 and V3 have RS patterns.
V4 has an Rs pattern.
V5 and V6 have qR patterns.
P and T are upright in all leads.
There is moderate clockwise rotation.

Vertical Rotation.

A: Sitting.

VI to V3 are similar to the control.

V4 has an Rs pattern with decrease in R and increase in s.

V5 and V6 have qRs patterns.

There has been further clockwise rotation.

B: Standing.

VI to V3 are similar to the control but T is diphasic in VI and reduced in V2 and V3.

V4 has an Rs pattern with decrease in R and increase in s.

V5 and V6 have qRs patterns with increase in q.

In V4 to V6 T is diphasic and the ST segment is slightly depressed.

There has been clockwise rotation and the heart has also become more vertical.

C: 45^o head up.

The patterns are similar to those in B but T remains upright in VI, V4 and V5.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S.
V2 and V3 have Rs patterns with increase in R.
V4 has an Rs pattern.
V5 has a qRs pattern with increase in R.
V6 has a qR pattern.
T is increased in V3 to V6.
Some displacement to the right has occurred.

F: Left Lateral.

VI to V4 are similar to the control but T is inverted in VI and reduced in V2 to V4.

V5 and V6 have qR patterns with increase in q and R.

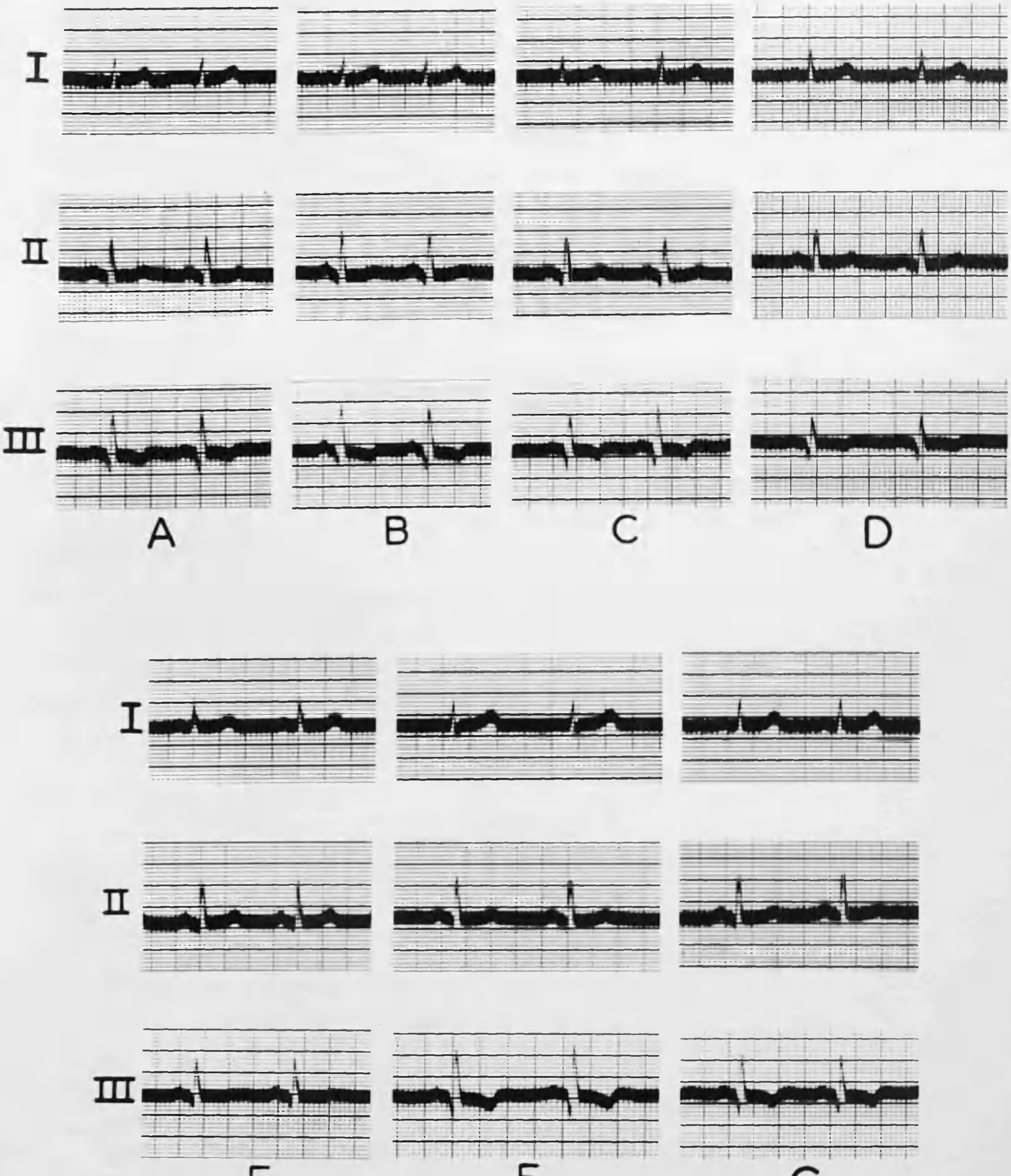
T is increased in V6.

Some displacement to the left has occurred along with forward rotation of the apex.

G: Prone.

In VI S is increased and T inverted. In V2 to V4 T is reduced. In V6 q, R and T are increased. The heart has become more horizontal with forward rotation of the apex.

STANDARD LIMB LEADS



ABNORMAL. R.K.

Diagnosis: Coronary Insuffiency. Age 66 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and T waves and an R pattern.

Lead II has upright P and T waves and a qR pattern.

Lead III has upright P and inverted T waves and a QR pattern; the RT segment is slightly depressed.

Vertical Rotation.

A: Sitting.

Lead I has an Rs pattern.

Lead II has a qR pattern with increase in q and R; T is reduced.

Lead III has a QR pattern with increase in Q and R; T is more deeply inverted.

B: Standing.

Lead I has an Rs pattern with reduction in R.

Lead II has a qR pattern with increase in q and R; T is reduced and the RT segment is slightly depressed.

Lead III has a QR pattern with increase in Q and R; T is more deeply inverted and the RT segment is more depressed.

P is increased in leads II and III.

C: 45° head up.

The changes are similar to those in B but are less marked.

In A,B and C there has been a shift of the QRS axis to the right.

Horizontal Rotation.

E: Right Lateral.

Lead I shows increase in R.

Lead II shows reduction in q and increase in R; T is increased.

Lead III has a qR pattern with increase in R; T is shallow and diphasic but mainly upright; the RT segment is isoelectric.

F: Left Lateral.

Lead I has an Rs pattern; T is increased.

Lead II has a qR pattern with increase in R.

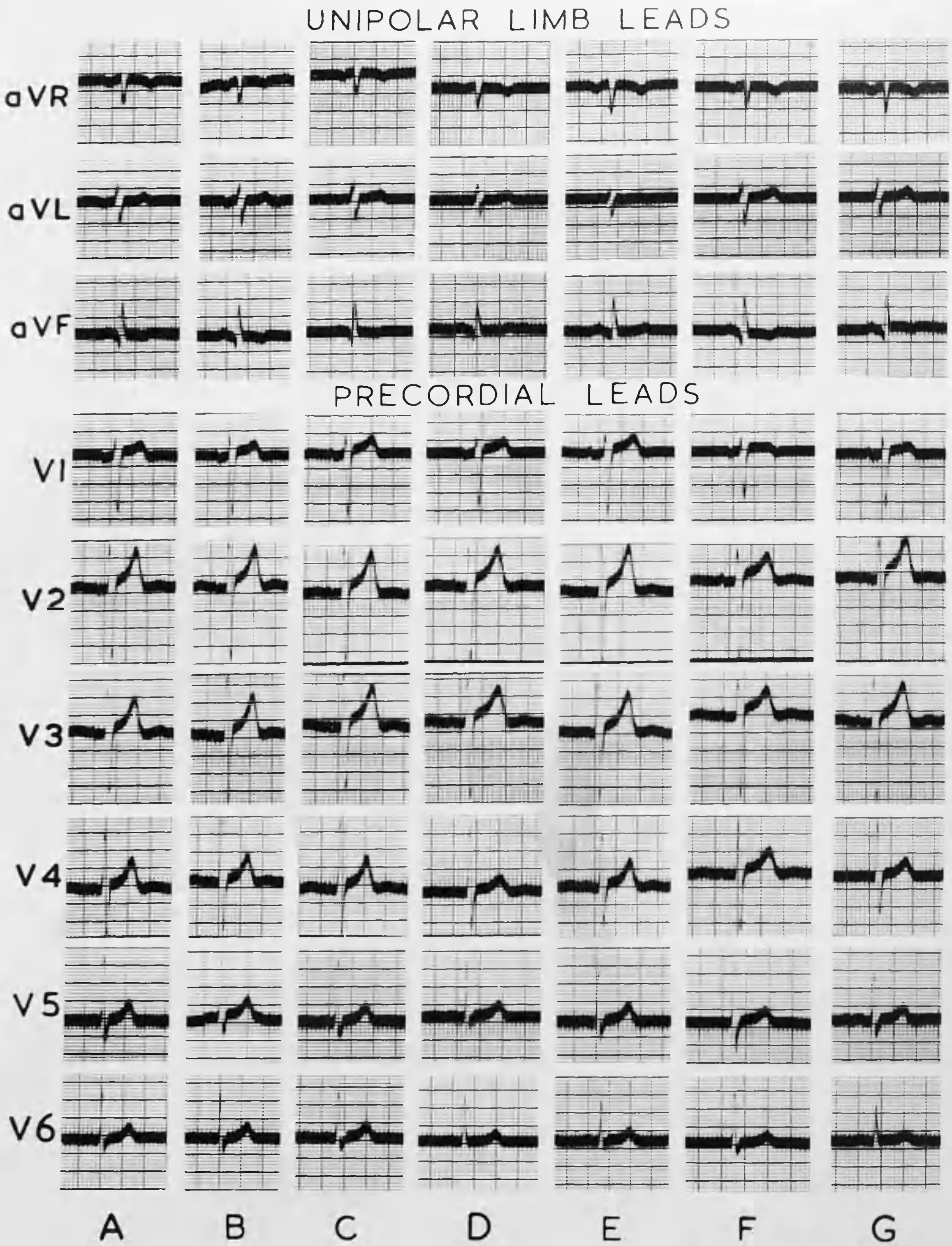
Lead III has a QR pattern with increase in Q and R; T is more deeply inverted and the RT segment more depressed.

G: Prone.

Lead I shows increase in T.

Lead II has a qR pattern with increase in R.

Lead III has a QR pattern with increase in Q and R; T is more deeply inverted and the RT segment more depressed.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
B
C
D
E
F
G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and an rS pattern. It faces the cavity of the right ventricle.

aVL has flat P and upright T waves and an RS pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and shallow diphasic T waves and a qR pattern; the RT segment is slightly depressed. It faces the epicardial surface of the left ventricle.

The heart is vertical with forward rotation of the apex.

Vertical Rotation.

A: Sitting.

aVL shows increase in S and T.
aVF shows increase in q and R; T is slightly inverted.
The heart has become more vertical.

B: Standing.

aVL shows increase in S and T.
aVF shows increase in P,q and R; T is inverted and the RT segment is more depressed.
The heart has become more vertical.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.

E: Right Lateral.

aVR shows increase in S; P and T are more deeply inverted.
aVL shows decrease in R and increase in S; T is practically flat.
aVF shows decrease in q and increase in R; P is increased; T is upright and the RT segment is isoelectric.
There has been backward rotation of the apex.

F: Left Lateral.

aVL shows increase in S and T.
aVF shows increase in q and R; T is inverted and the RT segment is more depressed.
There has been forward rotation of the apex.

G: Prone.

aVL shows increase in R and S; T is increased.
aVF shows increase in R; T is slightly inverted.
The heart has become more horizontal and there has been some forward rotation of the apex.

PRECORDIAL LEADS.

D: Supine.

VI to V3 have rS patterns.
V4 and V5 have Rs patterns.
V6 has an R pattern.
P is diphasic in VI and notched in all other leads; T is upright in all leads.
There is marked clockwise rotation.

Vertical Rotation.

A: Sitting.

VI and V2 have rS patterns.
V3 and V4 have RS patterns.
V5 and V6 have Rs patterns.
T is increased in V4 to V6.
There has been some clockwise rotation and the heart has become more vertical.

B: Standing.

The changes are similar to those in A.

C: 45° head up.

The changes are similar to those in A and B.

Horizontal Rotation.

E: Right Lateral.

VI has an rS pattern with increase in r and S.
V2 and V3 have RS patterns.
V4 has an Rs pattern with reduction in R.
V5 and V6 have Rs patterns.
T is increased in all.
Displacement to the right has occurred along with some clockwise rotation and backward rotation of the apex.

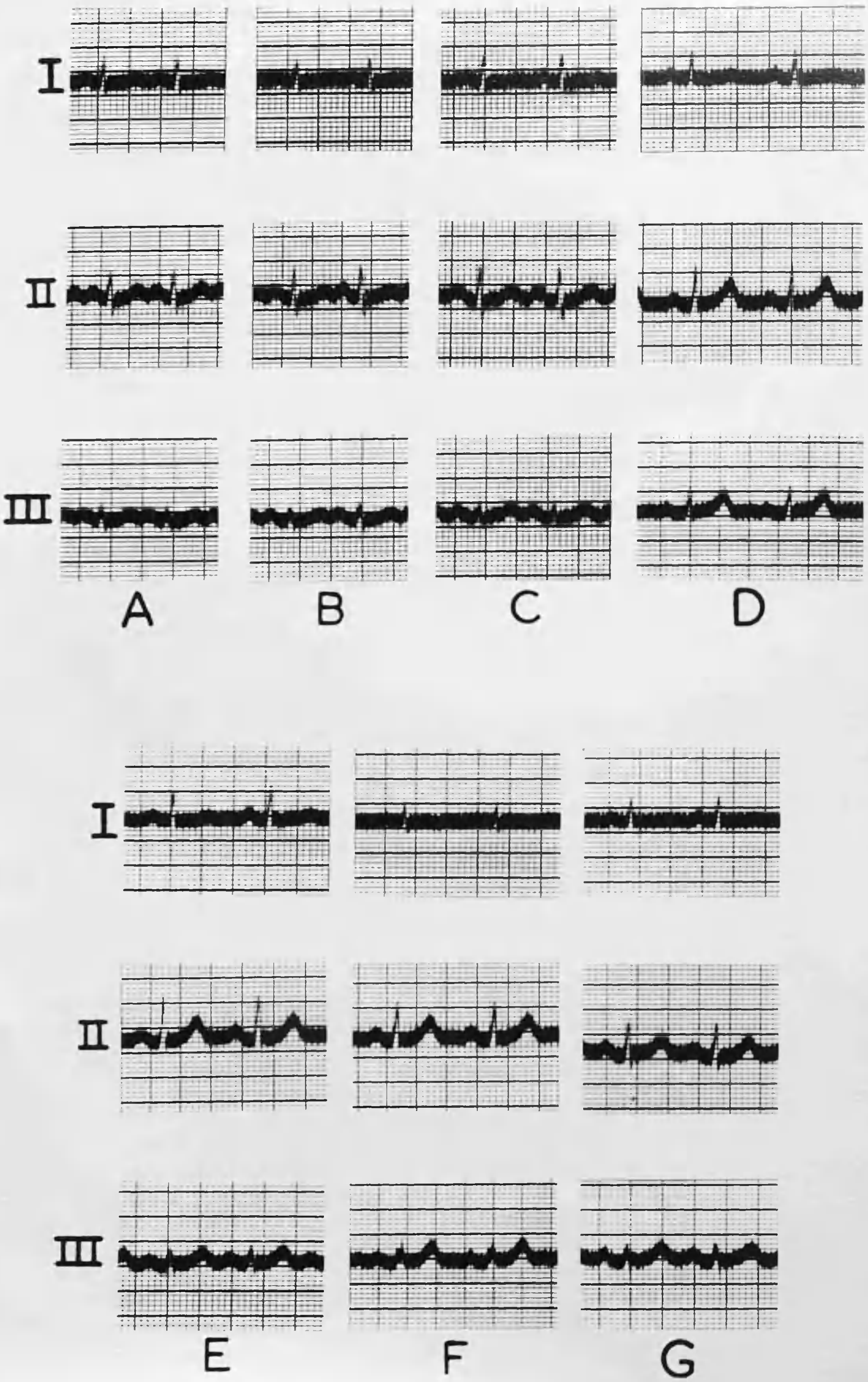
F: Left Lateral.

VI to V3 have rS patterns with reduction in r.
V4 has an RS pattern.
V5 and V6 have Rs patterns.
T is diphasic in VI; reduced in V2 and V3 and increased in V4 to V6.
Displacement to the left has occurred.

G: Prone.

The patterns are similar to the control series but there is reduction of R and T in V6.
The heart has become more horizontal.

STANDARD LIMB LEADS



CASE NO. 41 PLATE 171a

ABNORMAL. H.W.

Diagnosis: Anterior Myocardial Infarction (healing). Age 49 years.

STANDARD LIMB LEADS.

D: Supine.

Lead I has upright P and low upright T waves and an R pattern.

Leads II and III have upright P and tall upright T waves and Rs patterns.

Vertical Rotation.

A: Sitting.

Lead I has an Rs pattern.

Lead II shows reduction in R and increase in s; P is increased and T is reduced.

Lead III shows reduction in R; P is increased and T is reduced.

B: Standing.

Lead I has an Rs pattern with reduction in R; T is flat.

Lead II shows reduction in R and increase in s; P is increased and T is reduced; the ST segment is slightly depressed.

Lead III shows reduction in R; P is increased and T is reduced; the ST segment is slightly depressed.

C: 45° head up.

The changes are similar to those in B but are less marked.

Horizontal Rotation.

E: Right Lateral.

Lead I shows increase in P, R and T.

Lead II shows increase in P, R and s; T is slightly reduced.

Lead III shows reduction in R and T.

F: Left Lateral.

Lead I has an Rs pattern with reduction in R; P is flat and T is slightly inverted.

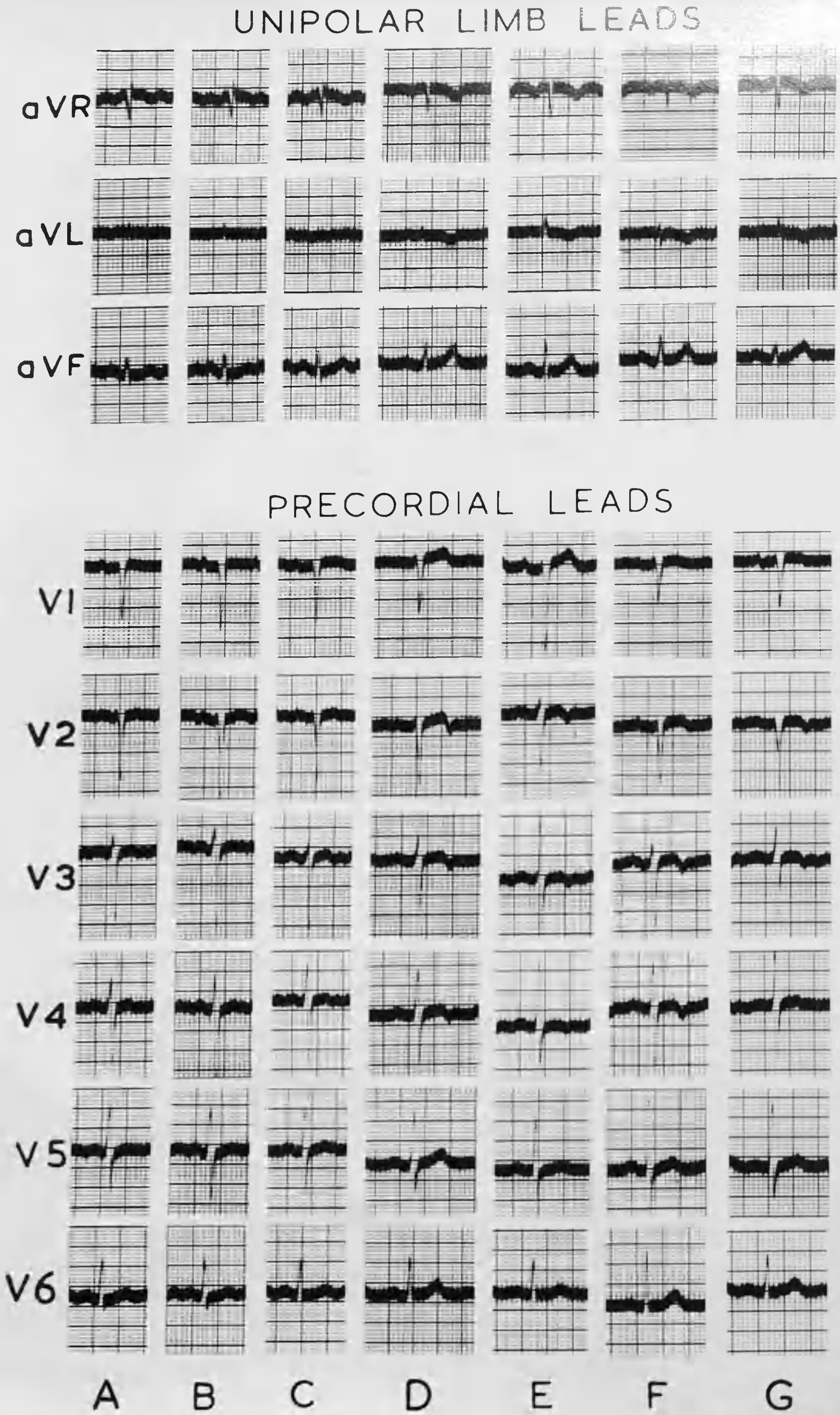
Lead II shows increase in P and reduction in s; T is reduced.

Lead III has a splintered R pattern; P is increased and T is reduced.

There has been a shift of the QRS axis to the right.

G: Prone.

Lead I shows reduction in R; T is flat. Leads II and III show reduction in R and T and increase in s and P.


UNIPOLAR LIMB LEADS
aVR
aVL
aVF
PRECORDIAL LEADS
V1
V2
V3
V4
V5
V6
A
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D
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G

UNIPOLAR LIMB LEADS.

D: Supine.

aVR has inverted P and T waves and a QS pattern.

aVL has upright P and inverted T waves and an r pattern. It faces the epicardial surface of the right ventricle.

aVF has upright P and T waves and an Rs pattern. It probably faces the epicardial surface of the left ventricle.

The heart is vertical.

Vertical Rotation.
A: Sitting.

aVR has a Qr pattern; T is less inverted.

aVL has an rs pattern; P is slightly inverted and T is flat.

aVF shows reduction in R; P is increased and T is reduced.

There has been clockwise rotation.

B: Standing.

aVR has a Qr pattern; T is less inverted.

aVL has an Rs pattern; P is slightly inverted and T is flat.

aVF shows increase in s; P is increased and T is reduced; the ST segment is slightly depressed.

There has been clockwise rotation.

C: 45° head up.

The changes are similar to those in B but are of less degree.

Horizontal Rotation.
E: Right Lateral.

aVR has a Qr pattern; P is more deeply inverted.

aVL has an R pattern; T is less inverted.

aVF has an Rsr' pattern with increase in R; P is increased and T is reduced.

There may have been some clockwise rotation and backward rotation of the apex.

F: Left Lateral.

aVR has a reduced QS pattern; T is less inverted.

aVL has an rS pattern; T is more inverted.

aVF has an R pattern; T is reduced.

There has been forward rotation of the apex, and aVL now faces the infarcted surface more directly.

G: Prone.

aVL has an R pattern. aVF has an Rs pattern with reduction in R. The heart has become more horizontal.