A Theoretic Analysis of the Effects of Dipole Eccentricity upon the Manifest Vectors, the Manifest QRS Loops and the Potential of the Central Terminal

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Assuming homogeneous conductivity and a limitless medium, a theoretic analysis accomplished by employing a model leads to the conclusion that dipole eccentricity produces a systematic error in the magnitude and direction of the instantaneous manifest vectors, the manifest QRS loops and the potential of the central terminal. Exaggeration of the electrical rotation of the heart and other electrocardiographic problems are discussed as possible manifestation of dipole eccentricity. Certain correlations applying to spatial vectorcardiography are made from simultaneous study of the theoretic back potential, the AP lead of the cube, and the potential of the central terminal.

In a previous paper the author reported the results of a theoretic analysis of the errors incident to the assumption that the cardiac dipole remains at the center of the geometric figures commonly employed as frames of reference in vectorcardiographic technic. This study led to the investigation of the Einthoven triangle from the same standpoint. Accordingly, it was felt that it would be advantageous to be able to measure, simultaneously, the three extremity potentials, the potential of the back electrode of the tetrahedron, and the potentials at the two electrodes employed in measuring the anterior-posterior projections of the vectors of the cube.

At the same time that the construction of the model designed for this purpose was completed, Frank's papers on the same subject appeared in the literature. Frank's approach to the analysis of errors introduced into the manifest direction and magnitude of the cardiac potentials by eccentricity of the dipole involved restricting the dipole to the frontal plane and to a single location during the inscription of the QRS complex. Frank indicated, however, that he was completely aware that an anterior-posterior component of the dipole axis would increase the error and also that movement of the dipole during the process of accession would modify the error.

The approach which the author had projected, employing the above mentioned model, involves moving the dipole in three-dimensional space, and studying the effect on the manifest direction and magnitude of the cardiac vector as plotted on the Einthoven triangle. At the same time the potential of the central terminal is studied for each observation. The effects of eccentricity errors as they would appear in the horizontal components of the loops of the tetrahedron and the cube are also investigated.

The employment of a model contributes to greater ease of calculation and to visualization but not to great accuracy of measurement. However, the mathematical formula which might have been employed instead of the model is so cumbersome as to be impractical and it is the writer's opinion that the calculations made from the model are sufficiently satisfactory for the purposes of this study.

Method

The method involves the assumption that the wave of excitation may be represented by a single dipole of equal electrical moment located at the center of the wave of excitation. Frank has analyzed one of the errors involved in this assumption. He found that this error is inconsiderable until the angle between the perpendicular to the center of
the wave and the line drawn from the center of the wave to the electrode is less than 18 degrees. Except in discussion this area was not invaded in this analysis. The substitution of the single dipole for the wave of excitation simplifies the formula for calculating the potential at a point, for integration is thus made unnecessary. Further simplification is effected by assuming that the conducting medium is homogeneous and limitless. The formula then becomes

\[ V = \frac{E \cos \theta}{d^2} \]

Where \( E \) is the electrical moment of the dipole; \( \theta \) is the angle between the axis of the dipole and the line drawn from the midpoint of the dipole to the electrode; and \( d \) is the distance between the midpoint of the dipole and the electrode.

The model employed is seen in figure 1. The rod, \( E \), is the vector representing the direction of the dipole and the magnitude of the electrical moment of the dipole. Obviously, the magnitude is kept constant in this study. The dipole is located at the center of the rod. This point is connected to the points \( R, L, F, B, X \) and \( Y \) by elastic cords, which become the lines upon which the vector is projected and upon which the distance from the dipole to each of these electrode positions is measured. \( R \) is the right shoulder; \( L \) is the left shoulder, \( F \) is the left leg, and \( B \) is the position of the back electrode of the tetrahedron. \( X \) and \( Y \) are the anterior and posterior electrode positions employed in the measurement of the anterior-posterior projection of the vectors in the cube method of vectorcardiographic recording. The vector is seen to be double-ended so as to facilitate projection of positive and negative values upon the lines without necessitating the difficult maneuver of extending the lead lines for this purpose. The rod, \( E \), is carried by a carpenter's gage which permits linear movements of the dipole. The carpenter's gage is carried by a vertical quarter-circle made of plywood, which is in turn carried at a 90 degree angle by a similar quarter circle both of which are adjustable. It is thus possible to orient the vector in a multitude of directions and relations to the frontal plane and then study the effects of linear movement of the dipole.

The value of \( E \cos \theta \) is obtained by dropping perpendiculards from the appropriate end of the vector (positive or negative) to the line connecting the midpoint of the dipole to the electrode positions \( R, L, F, B, X \) and \( Y \), and measuring the projections upon these lines with a metric rule. The distances from the midpoint of the dipole to the electrode positions \( R, L, F, B, X \) and \( Y \) are measured directly in centimeters. For each observation the values for \( E \cos \theta \) (the projection upon the lines) and the distances are tabulated for each of the electrode positions. The theoretic potential at each electrode was then calculated from the formula \( V = E \cos \theta / d^2 \). The theoretic potential of the central terminal was then computed for each observation and this subtracted from all potentials commonly measured against the central terminal.

In plotting the manifest vectors on the frontal plane the two largest potentials among \( V_r \), \( V_l \), and \( V_p \) were employed. There was no very good reason for not employing the standard limb leads I, II and III except that it would have involved additional tabulation. The results would have been the same.

The method is necessarily subject to error in measurement, but it makes it possible to visualize and to study the general order of the variations due to change of position of the dipole in which we are interested. If the measurements are plotted on coordinate paper against the measured linear movements of the dipole, it becomes possible to recognize as inaccurate those measurements which fail to fall on a smooth curve of the general form shown in figure 2. This set of curves was derived from a previous analysis.\(^1\)
Fig. 2. Curves derived from a previous analysis showing the potential variation as a dipole moving in the line of its own axis approaches and passes an electrode position (a) when the electrode is on or close to the line of motion; (b) when the electrode is moved further away from the line of motion, and (c) when the electrode is at a still greater distance from the line of motion.

One question which arises immediately involves the location of the frontal plane. For most of the purposes in this analysis it is assumed that the frontal plane is located 4.5 cm. behind the anterior wall of the chest and that the remaining 16.5 cm. of the anterior-posterior diameter of the chest lies behind it. Various opinions will be expressed regarding this point. The frontal plane may actually be so far back as to divide the chest into anterior and posterior halves. This problem will be taken up in the discussion.

**RESULTS**

**Results in Radial Eccentricities**

The first motion of the wave of excitation studied is depicted in figures 3A and 3B. The axis of the vector is at 0 degrees in its frontal plane projection and in space it points 30 degrees behind the frontal plane (antero-posterior component). As shown in the figure the first position is centric. The reader is looking at the negative surface of the wave of excitation. Each succeeding position studied is 1 inch back and to the left of the preceding one. The motion is in the spatial direction of the vector and is accomplished simply by moving the slide of the carpenter’s gage 1 inch for each change of position. The parallel positions of the wave of excitation as shown in figure 3A, are regarded as possible positions of waves of excitation in the right ventricle, septum or left ventricle in various human hearts.

The manifest vectors resulting from the study of this motion are seen in figure 3B. The vector numbered 1 is the manifest vector for the centric position of the dipole. The vectors numbered 2, 3, 4, 5 and 6 result from moving dipole to the progressively more eccentric positions as described above. The vector, 1, for the centric dipole possesses the correct magnitude and direction. It is to be noted that as the wave of excitation moves backward and to the left the manifest vector rotates counterclockwise and becomes progressively shorter (see vectors 1 to 6, fig. 3B).

In this motion the dipole is not depicted as occupying a position anterior to the frontal plane. This is regarded as a deficiency. In the succeeding studies this deficiency is remedied.

Figures 4A and 4B show the results of a study of the same kind of motion of a dipole whose representative vector in space is at +20 degrees, as projected on the frontal plane, and again 30 degrees behind the frontal plane. Here, again, the manifest vector is seen to rotate counterclockwise with increasing degree of eccentricity. It also becomes shorter if we consider only those vectors representing the centric position in the frontal plane, vector 0 of figure 4B, and the succeeding positions behind the frontal plane, vectors 1, 2, 3, 5 and 6 of the same figure. These do not at first rotate counterclockwise as rapidly as was seen for the first motion studied at 0 degrees, but they become shorter more rapidly. The two positions designated by the negative numbers, \(-1\frac{1}{2}\) and \(-1\), are anterior to the frontal plane. Their manifest vectors are rotated clockwise from the true direction represented by the vector 0, and they are longer.

Figures 5A and 5B show the variation of the magnitude and direction of the manifest vector when the actual vector is again pointing 30 degrees behind the frontal plane and its projection on the frontal plane is +45 degrees. Here we note that the manifest vectors for the eccentric positions rotate clockwise in contrast to those of the previously studied motions. They become shorter less rapidly than those
Figs. 3A and B. The spatial axis of the dipole is at 0 degrees as projected on the frontal plane and the angle between the dipole axis and the frontal plane is 30 degrees. The direction of the eccentric movement is the same as the axis of the dipole. The upper diagram furnishes a spatial visualization of the waves of excitation producing the manifest vectors shown in the lower part of the figure. The reader is looking at the negative surfaces of the waves of excitation. As the dipole moves to more and more eccentric positions it is seen that the manifest vectors deviate counterclockwise in direction and become smaller in magnitude.

Figs. 4A and B. The spatial axis of the dipole is at +20 degrees and the angle between the dipole axis and the frontal plane is 30 degrees. The eccentric motion has the same direction. It is seen that as the wave of excitation is moved leftward from the centric position to more and more eccentric positions, as visualized in the upper part of the figure, the manifest vectors shown in figure 4B deviate more and more counterclockwise in direction and become smaller. The deviation in direction is smaller than for the dipole at 0 degrees and eccentricity in the same axis, but the change in magnitude of the manifest vectors is greater. Movement of the dipole to the right and anterior to the frontal plane, vectors $-1\frac{1}{2}$ and $-1$, causes the manifest vectors to deviate clockwise and become longer.

Figs. 5A and B. The spatial axis of the dipole is at +45 degrees as projected on the frontal plane and the anterior-posterior component of the dipole axis is again 30 degrees. The direction of the eccentricity is the same as the axis of the dipole. It is seen that as the dipole becomes more eccentric to the left of center, the manifest vectors deviate clockwise in direction and become smaller.

for the dipole at $+20^\circ$ (fig. 4B), and more rapidly than those for the actual dipole at 0 degrees (fig. 3B).

Discussion. It is important to note that the motion passes through the center of the Einthoven triangle in the frontal plane. It is also important to note that dipole axes form a 30 degree angle with the frontal plane and point backward and that the motion also has this same direction. Thus, in the motions depicted above, as the dipole moves away from the center of the triangle it not only increases its distance from the center as projected on the frontal plane but at the same time increases its distance from the frontal plane. Both distances are important, for both alter the spatial relationship of the dipole to the electrode positions.

It is apparent from the results shown above
that radially eccentric positions of the dipole in three dimensions produces marked deviation in both the magnitude and the direction of the manifest vector. When the axis of the dipole and the direction of the motion is at +45 degrees, the deviation in direction is clockwise. When the direction of the dipole and motions is at +20 degrees, and at 0 degrees, the deviation is counterclockwise. It is evident that at some intermediate axis the deviation of direction of the manifest vector must fail to occur. Geometric consideration alone makes it clear that a simple radial motion of a dipole whose axis, as projected upon the frontal plane, is at +30 degrees will produce no error in direction at all. In figure 6 it is apparent, if the dipole has a radial direction of +30 degrees as projected upon the frontal plane and moves in the same direction in the linear manner employed in this study, R1 to R2, etc., that as the dipole becomes more and more eccentric the projection (E cos θ) of the vector upon the line joining the midpoint of the dipole to L will remain equal to the corresponding projection for F as both diminish rather rapidly. At the same time the distance, as it shortens, also remains equal for both electrode positions. As a result the potential at F will always equal the potential at L, and the direction of the manifest vector remains the same throughout the motion; but the magnitude diminishes rapidly, since the potentials are reduced rapidly at L and F and also at R (the same conclusion applies to dipoles of radial direction at axes, -90 degrees and at +150 degrees). With the dipole pointing in the opposite direction from +30 degrees, -90 degrees, and +150 degrees, i.e., toward the apices of the triangle, and with the same direction for the radially eccentric motion (toward the apices of the triangle), there is also no deviation of direction of the manifest vector, but in these cases the magnitude of the manifest vector behaves in a different manner for it usually becomes longer with increasing eccentricity.

Here it becomes important to consider separately the effect of the relationship of the dipole to the frontal plane. (See fig. 7.) We shall consider the dipole of axis +90 degrees as projected in the frontal plane and the effect of eccentricity upon the magnitude of the manifest vector when the dipole remains in the frontal plane, when it remains behind the frontal plane, and finally when it is anterior to the frontal plane. If the dipole whose axis is at +90 degrees as projected on the frontal plane (see fig. 7) remains in the frontal plane as it approaches F, the magnitude of the potential at F would follow a hyperbolic function for degrees of eccentricity applicable to the human heart (fig. 7) even if the dipole has some backward direction. Under these conditions the magnitude of the manifest vector actually increases. Even though the potentials at L and R are diminishing at the same time, they do not compensate entirely for the effect of increase of the potential at F upon the magnitude of the manifest vector. This is due largely to the fact that increasing eccentricity toward F increases the distance between the dipole and the electrode positions R and L, but not as rapidly as it decreases the distance from the dipole to F. However, if the dipole is behind the frontal plane and points considerably backwards, and if it is also at some distance from the frontal plane (fig. 7) or becomes so as it moves to more and more eccentric positions, the curve for the potential at F may change to the curve 60 degrees PFP (fig. 7). Under these conditions the magnitude of the manifest vector will first tend to become greater and then to diminish as the degree of eccentricity increases. In the writer's opinion the largest vectors which occur during the inscription of the QRS complex in the normal heart have a considerable backward direction when the projection of the axis upon the frontal plane is at +90 degrees.

On the other hand, if the dipole is anterior to the frontal plane and has the same axis of +90 degrees
Fig. 7. The rectangular border of the figure represents a sagittal view of the chest. The lines PF and P'F' represent, respectively, an anterior and a mid-position of the frontal plane. F is the location of the left leg electrode for frontal plane, PF and F' is the location of the left leg electrode for frontal plane, P'F'.

The figure represents a series of dipoles 1', 2', 3 and 4, all having an axis of +90 degrees as projected on the frontal plane, and each closer to the left leg electrode than the preceding dipole in the series. The motion of the dipole is studied first when its axis has an anterior-posterior component of 60 degrees represented by vectors a', c', e and g, and then again giving the axis of the dipole an anterior posterior component of 30 degrees represented by vectors b', d', f and h. The effect of the downward movement of the dipole when the dipole is anterior to the frontal plane is studied by measuring the theoretical potentials produced at F' by dipoles 1 and 2, and at F' by dipoles 3 and 4. The effect of the movement of the dipole when the dipole is posterior to the frontal plane is studied by measuring the theoretic potential produced at F by dipoles 1', 2' 3 and 4. The effect of the movement of the dipole when the dipole remains in the frontal plane is studied by measuring the theoretic potential produced at F' by dipoles 1', 2', 3 and 4.

The curves in the upper left hand corner show the variation of the potential at the left leg electrode under the conditions indicated by the labels: 30 degrees A.F.P.; the dipole axis has an anterior-posterior as projected on the frontal plane, and if it has, again, the same backward component as just described for the cases at some distance behind the frontal plane, the magnitude of the potential at F will be greater than is the case for the similarly directed dipole behind the frontal plane, and with increasing eccentricity the potential at F will increase in a hyperbolic order (curve 60 degrees AFP, fig. 7) even though the dipole is at some distance from the frontal plane. Thus, if the dipole is anterior to the frontal plane such eccentricities may be expected to produce a magnification of the magnitude of the manifest vector, but the manifest vector for the dipole anterior to the frontal plane will be smaller than the manifest vector for the dipole in the frontal plane because of the effect of the anterior position of the dipole in reducing the potentials at L and R, when the dipole axis has a backward component. Figure 7 illustrates these points.

If the dipole is rotated away from the +90 degree axis, e.g., toward a +75 degree axis, maintaining its same backward direction, the effect upon the potential at F is the same as increasing the angle between the axis of the dipole and the frontal plane; the spatial relationship of the dipole to F is changed so that the curve for the potential at F at first rises with increasing radial eccentricity and then descends (curve 60 degrees PFP, fig. 7). It must also be noted that as the axis of the dipole is swung away from the +90 degree axis, e.g., to +75 degrees, the influence of the other two electrodes upon the magnitude of the manifest vector begins to increase. The effect of these two factors is that at first the manifest vectors increase, and then they decrease with increasing eccentricity (fig. 11B). When the dipole axis is swung to +45 degrees the manifest vectors simply decrease in magnitude with increasing eccentricity (fig. 5B).

It is important to note that when the dipole axis is swung away from the +90 degree projection on the frontal plane as just described, changing its position with reference to the frontal plane also alters the direction as well as the magnitude of the manifest vector. Measurements were made which involved keeping constant the spatial axis of the dipole and its eccentric position as projected on the frontal plane, while the dipole was moved in a line perpendicular to the frontal plane from positions anterior to positions posterior to the frontal plane. In all cases the anterior-posterior component of the dipole axis was 30 degrees and the dipole pointed backward. When the axis of the low left eccentric component of 30 degrees, and the dipole is anterior to the frontal plane; 30 degrees F.P.P., the dipole axis has a 30 degree anterior-posterior component and remains in the frontal plane; 30 degrees F.P.P., the dipole axis has an anterior posterior component of 30 degrees and remains behind the frontal plane. The other labels correspond.
dipole was at +65 degrees as projected upon the frontal plane, then moving the dipole anterior to the frontal plane produced a shortening of the magnitude of the manifest vector and a reduction of the clockwise deviation in its direction. When the dipole was moved back of the frontal plane the magnitude of the manifest vector diminished again, but more rapidly, and its direction again swung toward the true direction. With the axis of the dipole at 0 degrees as projected on the frontal plane, movement anterior to the frontal plane produced the same effect on both magnitude and direction of the manifest vector. Movement of the dipole of 0 degree axis back of the frontal plane causes the manifest vector to become more counterclockwise in direction and larger in magnitude. With the dipole at the low left eccentric position and the axis at +30 degrees as projected on the frontal plane, moving the dipole forward had only slight effect on either magnitude or direction. However, these effects depend upon the degree of eccentricity and the magnitude of the anterior-posterior component of the dipole axis.

We arrive, then, at the conclusion that if the spatial vector of an eccentric radial dipole behind the frontal plane and at fixed angle with the frontal plane (of say 30 degrees) is swung about the center of the triangle so as to describe a truncated cone whose projected apex is at the center of the triangle, (fig. 8), the following phenomena will be noted:

The direction of the manifest vector at +90 degrees will not be deviated. As the spatial vector swings to the left (the reader's right) the direction of the manifest vector is deviated clockwise, at first slightly. As the spatial vector is swung further to the left the extent of the deviation in direction increases. As the spatial vector approaches the +30 degree axis the deviation diminishes again and when the +30 degree axis is reached, the deviation is again 0. As the spatial vector is swung to the left of +30 degrees the deviation becomes counterclockwise and is first small, then large, and finally small again until the −30 degree axis is reached where again no deviation occurs (fig. 8).

With the spatial vector at +90 degrees the magnitude of the manifest vector is greater than would be expected for the centric dipole. As the spatial vector swings toward +30 degrees, as projected on the frontal plane, the magnitude diminishes. At +30 degrees the magnitude is at its minimum, and then it begins to increase again. The same cycle is repeated through each 60 degrees of the 360 degrees.

Increasing the degree of eccentricity, as projected upon the frontal plane, increases the extent of the changes in direction and magnitude of the manifest vector described above.

Increasing the anterior-posterior component of the axis shortens the manifest vector for any position of the dipole. In addition, if the anterior-posterior component is large, it may cause a dipole pointing toward the neighborhood of an apex of the triangle to produce a manifest vector which first lengthens and then shortens with increasing eccentricity instead of becoming progressively larger (fig. 9B).

If the dipole positions and directions depicted in figure 8 are moved anterior to the frontal plane the extent of the deviation in direction diminishes and the magnitudes of the manifest vectors diminish. Usually the manifest vectors are larger when the dipole is in the frontal plane than when the dipole is in either the

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**Fig. 8.** The figure shows only the general order of the eccentricity effects as the axis of the dipole is changed from +90 degrees to −30 degrees as projected upon the frontal plane. The solid tipped vectors of eccentric point of origin represent the true spatial axis of the dipole. The black tipped vectors are the corresponding manifest vectors. Neither the extent of deviation of direction nor variation in magnitude of the manifest vectors is intended to be quantitative.
Figs. 9A and B. A low left nonradially eccentric motion of the dipole whose axis is at 0 degrees as projected upon the frontal plane and making an angle of 32 degrees with the frontal plane. As compared with the radial dipole of similar spatial axis (figs. 3A and 3B), the counterclockwise deviation of the direction is greater. The vectors bearing the negative signs correspond to those of figure 9B.

Figs. 10A and B. The figures depict the low left nonradial eccentricity when the dipole axis is -20 degrees as projected on the frontal plane and the anterior-posterior component of the dipole axis is 55 degrees. The manifest vectors are seen to be deviated counterclockwise. The magnitude of the manifest vector becomes larger, and then smaller with increasing eccentricity.

In this figure the vectors labeled -3, -2 and -1 represent the manifest vectors for dipole positions anterior to the frontal plane and they are plotted after reversing the signs of the limb potential because these positions are felt to be applicable only to waves of excitation in the right ventricle. The vector in the frontal plane labeled 0 is plotted with and without reversed signs. In the most anterior position (-3) the dipole is anterior to the center of the triangle. The vector is smaller but has the true direction.

Figs. 11A and B. The low left nonradial motion of a dipole whose spatial axis is at 30 degrees as projected on the frontal plane and making an angle of 45 degrees with the frontal plane. The direction of the vector is deviated first clockwise and then counterclockwise by increasing eccentricity.

It would be extraordinary coincidence if all the eccentricities which apply to the human heart were to fall in the above described radial group. The axis of the dipole must frequently be nonradial and the motion which would represent waves of excitation in the right ventricle, interventricular septum or lateral wall of the left ventricle of various hearts must frequently lie below and to the left of the center of the triangle. Accordingly measurements were made with the dipole at axes of -20 degrees, 0 degrees, and +30 degrees, but with the line of motion below the center of
the triangle, so that the position of the dipole as it passes through the frontal plane is to the left or below the center of the triangle. The anterior-posterior component of the dipole was varied as will be noted.

Figure 10B shows the manifest vectors for a dipole whose axis is at $-20$ degrees and makes an angle of 55 degrees with the frontal plane (a rather large anterior-posterior component) and which moves through a line which passes through the frontal plane 1 3/4 inches below and 1 3/4 inches to the left of the center of the triangle.

Figure 9B shows the results of similar motion of a dipole of axis 0 degrees, making an angle of 32 degrees with the frontal plane. Figure 11B shows the result of a similar motion of a dipole of axis +30 degrees, making an angle of 45 degrees with the frontal plane.

Discussion. Obviously, with a spatial axis of $-20$ degrees, the manifest vectors for the nonradial dipole studies (fig. 10B) are all deviated more in the counterclockwise direction than would be expected for the radial dipole of the same axis and eccentricity. This is largely due to the downward displacement of the dipole as compared with the radial studies. This caused the direction of the axis of the dipole to point less toward the apex of the triangle than would a radially directed dipole of the same axis. Under these circumstances the deviation of the direction of the manifest vector is greater.

Thus, unlike the radially directed and radially eccentric dipoles for which the directional relationship to the apexes of the triangle is defined simply by the radial axis upon which the dipole lies and the distance from the center of the triangle, these nonradial dipoles must be oriented by defining (a) the radial axis upon which the dipole lies and the distance from the center of the triangle, and (b) the spatial axis of the dipole itself as projected upon the frontal plane. Both factors, as indicated, have their effect upon the manifest vector. This is found in Frank's formula.\(^3\) This same factor, in addition to the large backward element in the direction of the dipole, caused the manifest vector for this motion to become first larger and then smaller with increasing eccentricity, for the reasons given above. (See fig. 10B.)

With a dipole of axis 0 degrees, the low, left nonradial motion produces (fig. 9B) manifest vectors which are shorter than those of the centric dipole (compare with vector 0, fig. 3B) and which deviate rapidly counterclockwise in direction. All positions behind the frontal plane are deviated markedly in direction. The reasons are the same as those given above for the nonradial axis at $-20$ degrees. The positions most anterior to the frontal plane is almost equidistant from the three electrode positions R, L and F, and, therefore, the manifest vector assumes the true direction.

The low nonradial dipole at a spatial axis of $+30$ degrees produces, with increasing eccentricity, manifest vectors which deviate first clockwise and then, with increasing eccentricity, counterclockwise (fig. 11B). At the same time the vector becomes rapidly shorter, as is true for the radial dipole at $+30$ degrees. The reason for the change in deviation is made clear by figure 6. Throughout the motion the dipole is closer to F than it is to L. When both electrodes are facing the positive pole of the dipole, the potential at F is greater than at L. This causes the manifest vectors to point more toward F with increasing eccentricity. As the dipole moves behind the frontal plane, the two electrodes are finally facing the negative pole of the dipole, and F is now more negative than L. This causes the manifest vector to deviate counterclockwise. Certainly a similar inference can be drawn regarding eccentric dipoles with axes parallel to, or nearly parallel to, the other medians of the triangle.

Thus, the nonradial eccentric dipoles produce deviations in direction and magnitude of the manifest vector which are related, as might have been expected, to the same factors which were found to influence those produced by radial eccentricities. On the whole the effects of nonradial eccentricities as depicted here are greater than the effects of radial eccentricity.
GENERAL DISCUSSION AND APPLICATION TO THE PROBLEMS OF ELECTROCARDIOGRAPHY

Eccentricity and the Manifest Vectors

It is obvious that as a result of eccentricity it is possible to record manifest axes which range from more than +90 degrees to -30 degrees when the range of rotation of the actual vector (or dipole) has been only from 0 degrees to +45 degrees (figs. 3B, 4B, 5B). Furthermore, if we permit the eccentricity to be nonradial the degree of swing of the axis of the dipole necessary to achieve the same range of manifest axes is even less. It is suggested, then, that eccentricity of the dipole accounts for the exaggeration of the electrical rotation of the manifest QRS axis among human hearts, which most of us accepted as a fact years ago but could not account for. Although this is not the proper place to discuss this matter in detail, it should be pointed out that this exaggeration of the electrical rotations does not materially affect the validity of those analyses in which the electrical rotation of the heart has been employed as a factor.

Offhand, in the analysis of an electrocardiogram, it is not possible to know whether the manifest direction of a QRS axis is the true direction as projected on the frontal plane (for a centric dipole) or whether it is an erroneous direction for an eccentric dipole.

Regarding the magnitude of the manifest vector, it becomes clear that the anterior-posterior component of the axis of the dipole is not the only factor which causes the manifest vector to be small, as was formerly thought. In the eccentric position the manifest vector may become small even though it is not pointing very much backward (e.g., fig. 11B, vectors 2, 3, and 4). This is an adequate explanation for the fact that the QRS complex in many instances is small in all three limb leads and yet the back potentials do not indicate that the dipoles were pointing very much backward. However, another factor, the potential of the central terminal, enters into this problem.

It is important to point out here that one cannot conclude from the observations which have been made whether the frontal plane lies in the anterior position described above or in the midposition. For the most part within the range of dipole locations applicable to the human heart, the same order of deviation of the magnitude and direction of the manifest vector occurs in both cases; only the absolute magnitude and the extent of deviation of direction change, and these cannot be easily correlated with any measurable factor.

If we permit the waves of excitation (and their representative dipoles) employed in this study to represent the largest wave of excitation which occurs during the inscription of the QRS complex, and if we consider the fact that, among normal hearts, those which have electrocardiograms with maximum axis in the range +65 to +85 degrees have a greater magnitude for that maximum axis than do those with electrocardiograms showing the maximum axis at 0 degrees to -30 degrees, it becomes evident that this may be explained in one of several ways: (1) those with maximum axis at +65 to +85 degrees are centric so that direction and magnitude are correct, while those at 0 degrees to -30 degrees are most eccentric and, therefore, their direction is largely due to eccentricity and the magnitude small for the same reason; (2) those at 0 degrees to -30 degrees may be centric and have their correct direction and magnitude, while those at +65 to +85 degrees are low eccentricities which tend to increase the magnitude and also to rotate them rightward if they are pointing somewhat in that direction; (3) the difference may result from difference in the anterior-posterior component of the vectors; or (4) there may be a combination of two or more of these. Again the position of the frontal plane does not greatly influence the relative values for the manifest vectors at the various axes as projected on the frontal plane except for axes pointing considerably backward.

However, the position of the frontal plane will greatly affect the calculation of the potential of the central terminal. This will be discussed in more detail later.

It may be tempting at this point to permit
these manifest vectors of figures 3B, 4B, 5B, 9B, 10B and 11B to represent the mean manifest QRS vectors of various hearts, and it may be proper to do this. However, in dealing with errors resulting from eccentricity, it is necessary to remember that abstractions may not be dealt with in this manner until we are on more solid ground. The mean manifest QRS vector can have little meaning in this connection until we know more about probable effect of the eccentricity errors upon the manifest vector loops.

**The Effect of Dipole Eccentricity upon the Manifest QRS Loop**

Without pretense at mathematical accuracy we can make an analysis of the probable effect of eccentricity upon the manifest vector loops, if we employ the concept of the path of accession as published by Gardberg and Ashman in 1943.\(^4\) Figures 12, 13, 14, 15 and 16 depict this concept. This publication originated the concept that the actual spatial loop was about twice as long as it was broad and that the long axis of the loop was nearly perpendicular to the anatomic axis of the heart and, therefore, points, in general, to the left and backward in normal hearts. A similar conclusion regarding the general direction of the mean spatial axis of the QRS had been arrived at in an independent analysis of the gradient by Ashman and Byer. The elliptic loop shown, as derived from the waves of excitation of figures 12, 13, 14, 15 and 16, is the result of these analyses and careful trial and error comparison against normal tracings by Ashman. For years we have been employing the method of projecting this model “actual” loop upon a “frontal plane” by means of parallel light (fig. 18) or with the eye in the analysis of electrocardiograms and, in teaching, to show the effects of rotations of the heart on the standard limb leads, as well as in analysis of the ventricular gradient.

Application of the effect of eccentricity on each of the vectors of the five stages of the process of excitation depicted in figures 12, 13, 14, 15 and 16 is shown in figures 17 and 18. Only low left eccentricity effects are employed. The vectors of figure 17A represent the

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**Figures 12, 13, 14, 15 and 16.** The figures show the wave of excitation at 0.015 second, 0.020 second, 0.024 second, 0.04 second and 0.06 second, respectively. In each drawing the thick vector is the spatial vector derived from the wave or waves of excitation represented. The inaccuracy of such single "dipole" representation for this study is probably not great, but will receive attention in another paper. It is probable that in the right ventricle the wave of accession at 0.024 second has reached the epicardial surface in a larger area than is depicted here.
successive vectors for the waves of excitation shown above for a heart with anatomic axis at +30 degrees and rotated slightly clockwise about the anatomic axis, H. The loop shown in dashes is, then, the projection of the assumed actual spatial loop on the frontal plane. Assuming that the center of the heart is generally to the left of the midline and below the center of the triangle, the deviations due to eccentricity are approximated by applying to the vectors for each stage of excitation the error which is appropriate to, (1) the spatial direction of the vector, (2) the degree of eccentricity of the wave of excitation represented. Thus, the actual vector at 0.015 second is at about 0 degrees as projected on the frontal plane. The effect of eccentricity upon such vectors is shown on figure 17A, the vector being rotated counterclockwise. Since the wave of excitation is in the apexes of the ventricle at this moment, the degree of eccentricity is more than slight. Considerable deviation and some shortening are therefore, assigned to the vector. At 0.02 second the vector is at 25 degrees and the wave of excitation is in the apical half of the heart. Therefore, a deviation in the counterclockwise direction is assigned. The vector at 0.025 second is at +35 degrees and is therefore assigned a clockwise deviation. If it is permissible to represent the wave of excitation by a single dipole, this dipole is not extremely eccentric and the assigned deviation is not great. This will require further analysis. The vector at 0.04 second has an axis of 55 degrees and since the wave of excitation is in the lateral wall of the left ventricle the deviation is clockwise and is of considerable extent. The assigned deviation is to a direction of 78 degrees and the vector is lengthened. A deviation of the vector at 0.06 second is assigned in a similar manner.

The manifest loop is thus represented as the finely dotted loop of figure 17A. Thus, it is seen that the effect of eccentricity of the waves of excitation represented in this analysis is to make the loop appear to be wider and directed more toward the +90 degree axis than it actually is. It is important to realize that the effect is the same as would be accomplished by rotating the actual spatial loop more clockwise (fig. 18). Thus the effect of eccentricity is to make the loop appear to belong to a heart rotated more clockwise than it actually is. If the entire heart is moved to a more eccentric position to the left and/or downward from the center of the triangle the effect would be exaggerated.

Figure 17B shows the effect of eccentricity in the case of a heart which is rotated slightly
Fig. 18. The figure depicts the model of the spatial QRS loop (made of plexiglas) supported by a plastic rod which represents the anatomic axis of the heart. The wooden model of the ventricles supported by an extension of the rod serves to orient the reader with regard to the degree of anatomic rotation in each photograph. The series of photographs begins (1) with counterclockwise rotation around the anatomic axis and represents six rotational positions ending with strongly clockwise rotation around the anatomic axis. The shadows thrown by parallel rays of light upon the surface of the triangle represent the loops as projected on the frontal plane (the manifest loops as they would appear without eccentricity effects).
counterclockwise, and the anatomic axis is at +55 degrees. It is seen that the effect is to make the loop appear to belong to a heart which is rotated more strongly counterclockwise than it actually is.

Figures 19A, B, and C show the vectors of three nonrotated hearts at anatomic axes of +15 degrees, +30 degrees and +45 degrees, respectively. Application of eccentricity effects to these vectors indicates that the more vertical hearts are made to appear to be rotated clockwise while the more transverse hearts appear to be rotated counterclockwise.

The loop for the heart at +30 degrees will suffer no deviation in the direction of the manifest vectors if the eccentricities are radial, but the loop will appear to be much shorter (smaller) than it is. The finely dotted loop on the figure for the heart at +30 degrees (fig. 19B) is for a nonradial type of eccentricity such as that depicted for the waves of excitation of figure 11B. At +15 degrees and +45 degrees nonradial eccentricity will simply exaggerate the apparent rotation.

The above described phenomena indicate that the eccentricity effects upon the manifest loops make it appear that hearts are rotated more than they are and that some are made to appear to be rotated which are not. However, the error seems to follow a definite order and, in the writer’s opinion, it is simply the probable mechanism of the exaggeration of the electrical rotations of the heart which for some years some of us have been quite certain existed.

Accordingly, it now becomes possible to regard the vectors of figures 3B, 4B, 5B, 9B, 10B and 11B as mean spatial QRS vectors, for the effect of eccentricity upon the mean direction of the manifest loop seems to be subject to the same definitely orderly error which is summarized in figure 8.

Thus, it appears that the analysis which involves the rotation of a model “actual” loop described above contains this systematic error. It is important to emphasize that the presence of a systematic error in a correlation does not materially affect the validity of the correlation. The same systematic error must be intrinsic in the correlation of the spatial relationship of the anatomic axis, the mean QRS axis and the ventricular gradient, as published by Ashman, Gardberg and Byer. It is suggested that the validity of that correlation is not significantly affected by the presence of the eccentricity error. The potentials which produce the T wave are subject to the same error. This problem will be taken up in another paper.

It is apparent from the above analysis that shortening of the vectors of the loop, and thus of the mean manifest QRS, may result from eccentricity as well as from actual backward direction. Hereforefofore, foreshortening of the mean manifest QRS has been regarded as an indication of a relatively backward direction of the mean spatial QRS. Since we now know

![Fig. 19](http://circ.ahajournals.org/)

Fig. 19. The solid tipped vectors represent the successive waves of excitation depicted in figures 12, 13, 14, 15 and 16 when the heart is in the intermediate rotational position (not rotated around the longitudinal axis). In A and C the finely dotted loop is the manifest loop which results from the application of the approximate eccentricity errors, assuming that the eccentricity is of the radial type. In B the finely dotted loop results from the application of low nonradial eccentricity effects to the vectors. The manifest vector at .06 second in figure 19B should be moved further to the reader’s left. This has little effect on the general result.
that this may occur as a result of eccentricity, it is no longer disconcerting to find a discrepancy between the expected and observed back potential. We thus have a probable explanation for the rather low correlation between the back potential and the mean manifest QRS of the frontal plane. The variation of the potential of the central terminal is another factor in this problem.

Two special groups of cases are noteworthy: (1) Figure 17C, as stated above, depicts the eccentricity effects when the anatomic axis is at +5 degrees and the heart is rotated a bit clockwise. It is seen here that the effect of the eccentricity is to widen the loop a great deal and to shorten it. This produces the large Q3 type of electrocardiogram. It has heretofore been somewhat disconcerting that such a projection of our model spatial loop could only be obtained by placing the anatomic axis in a rather improbable position.

(2) Examination of the nonrotated "actual" loop with the anatomic axis at +30 degrees (fig. 19B) shows that nonradial eccentricity may cause such a loop to appear to be somewhat folded upon itself. In the same way, other loops for hearts with this or similar spatial orientations may be made to appear folded or twisted upon themselves. Such "spatial" loops have been recorded by Burch. It is not possible to determine the extent to which a recorded manifest loop owes its

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**Fig. 20.** The curves of each figure result from plotting the tabulations made in each of two studies, as the dipole is moved to more and more eccentric positions represented by the abscissae. $V_R$, $V_L$, $V_F$ and $V_B$ are the theoretic absolute potentials at R, L and F and B (see fig. 1). $V_R - CT$, $V_F - CT$, $V_L - CT$ and $V_B - CT$ are the theoretical potentials at $V_R$, $V_F$, $V_L$ and $V_B$ measured against the central terminal. $X - Y$ is the difference of potential between the anterior and posterior electrodes employed in measuring the anteroposterior projection of the vectors in the cube technique of vectorcardiography. $C$ is for a dipole at axis +20 degrees as projected on the frontal plane. $D$ is for a dipole at axis +45 degrees as projected on the frontal plane. In each instance the dipole axis makes an angle of 30 degrees with the frontal plane.
characteristics to eccentricity. It is probable that many loops owe little of their form to eccentricity, while others a great deal. While speculations can be made, actual correlation of individual manifest loop forms with eccentricity as determined from body measurements, including x-rays of the chest is difficult and subject to errors not considered here.

The Effect of Dipole Eccentricity upon the Central Terminal

For each of the dipole positions employed in this study the theoretical potential of the central terminal was calculated according to the formula:

\[ V_{ct} = \frac{V_R + V_L + V_F}{3} \]

Figures 20C and 20D show the effect of increasing radial eccentricity upon the potentials at R, L, F, B, and of the central terminal when the dipole and eccentricity are in the stated axes as projected on the frontal plane. In addition the difference in potential between X and Y, the two electrodes used in measuring the anterior-posterior component of the vectors of the cube, was calculated and these values appear in the same figures. Only the value for dipole in and behind the frontal plane were plotted.

Other results will be described for which no curves were drawn.

Discussion

With the dipole having an axis of +20 degrees as projected upon the frontal plane it is apparent that the potential of the central terminal becomes more and more negative at a rather rapid rate as the dipole is moved to the left and backward. With the dipole at an axis of +45 degrees as projected on the frontal plane, the potential of the central terminal again becomes more and more negative as the dipole is moved to the left and backward in a radial manner, but not as rapidly as it does when the axis of the dipole and of the motion is at +20 degrees. These measurements, together with other measurements which are not reproduced here, indicate that if the axis of the dipole and the motion are swung about as for figure 8 the potential of the central terminal goes through the following changes:

When the axis of the dipole is at +90 degrees and the eccentricity is in the same direction (see fig. 8), the potential of the central terminal is at a maximum. When the axis of the dipole and the eccentricity are in the +30 degree axis, the potential of the central terminal is at its minimum. The order of change is similar to that which characterizes the magnitude of the instantaneous manifest vector. Frank noted this phenomenon.

The absolute value of the potential of the central terminal will depend upon the factors which govern the magnitude of the manifest instantaneous vector. Among these are the anterior-posterior component of the spatial axis of the dipole, and the relationship of the location of the dipole to the frontal plane, that is, whether it is anterior to, in, or posterior to the frontal plane.

The range of values of the potential of the central terminal for the dipole of figure 8, when it is anterior to or in the frontal plane, is from a relatively large positive value at +90 degree axis, as calculated by Frank, to a value in the neighborhood of zero at +30 degrees. The range of values for the central terminal when the dipole is behind the frontal plane is from a slightly positive value at +90 degree axis to a large negative value at +30 degrees. These values may be taken to represent the peak values of the potential of the central terminal during the inscription of the QRS complex for loops having the mean spatial QRS axis represented by the spatial axes of the dipole of figure 8.

Increasing the backward component of the spatial axis of the dipole represented in figure 8 diminishes the potential of the central terminal for all dipole positions and axes represented, if the dipole is in or behind the frontal plane. If the dipole positions as represented in figure 8 are anterior to the frontal plane, increasing the backward component of the dipole axis increases the potential of the central terminal. The values for the potential of the central terminal for the dipole positions in the frontal plane will be intermediate.
between the values for the dipole positions anterior to and those posterior to the frontal plane, especially if the spatial axis of the dipole has a large anterior-posterior component. It becomes clear that the location of the frontal plane has greater significance for the value of the potential of the central terminal than it has for the absolute value of the manifest instantaneous vector. It is important to realize that the measurement of the instantaneous manifest vectors in practice is a purely relative matter, and therefore their absolute value has no importance. The employment of the potential of the central terminal as a reference in making chest leads for various purposes makes it mandatory that we have some interest in its absolute magnitude. No solution to this problem is offered here.

In Frank's study the axis of the dipole and the dipole were kept in the frontal plane. He also kept the loop fixed, although he gave the eccentricity a large number of directions. Since the dipoles of large electrical moment were kept at axes in the neighborhood of +65 degrees, the calculated potential of the central terminal was found under these circumstances to be generally large and positive. As he pointed out, it is generally much smaller when the dipole positions lie on the +30 degree axis. The circumstances under which he studied the variations are considered by the writer to be unrealistic for the human heart.

Under the circumstances herein considered applicable to the human heart, the order of variation of the central terminal potential during the inscription of the QRS complex must be analyzed on the basis outlined above. Accordingly, the curves of figure 21 show the potential variation of the central terminal which may be commonly reached during the inscription of the QRS complex, when the heart is in an eccentric position which, in the writer's opinion, is appropriate to the indicated mean spatial QRS axis. These are obtained by assigning to the values of the potentials of the central terminal those measurements of the theoretic central terminal potential which are appropriate to the magnitude of the dipole, its location, and its spatial axis during the process of accession as depicted in figures 12, 13, 14, 15 and 16.

Since it is at this time impossible to know the location of the frontal plane, no conclusion can be drawn as to whether the set of values depicted in the upper part of the figure or that shown in the lower part actually applies. No ready key to the solution of this problem is offered.

Correlation of Back Potentials with the Mean Manifest QRS Axis

One of the important problems which has been solved in this study, and which was referred to in a previous paper, is the finding by "spatial" vectorcardiographers that many normal QRS loops point forward or parallel to the frontal plane, that the mean back potential is negative or very small, although the actual vectors point backward to some extent, according to our view. This finding had been unexplained until recently, when it yielded to the analysis reported in a previous paper. One correlation remained to be made. This was the one represented by the observation that most loops which were made by the tetrahedron method and pointed forward were vertical in their frontal plane projections, while those which were rounded (and smaller) were more transverse. This phenomenon is revealed, on the curves $V_b$-CT of figures 20C and 20D, to be due to the variation of the potential of the central terminal. At +20 degrees, when the dipole is in an eccentric position, $V_b$ is negative but CT is even more negative and, therefore, $V_b$-CT is positive, making the vector point backward as recorded by the tetrahedron method. At an axis of +45 degrees, and a corresponding degree of eccentricity, $V_b$ is a bit more negative but CT is much less negative than at +20 degrees. Therefore, $V_b$-CT is negative and the vector points forward as recorded by the tetrahedron method. Actually, of course, the spatial vector points backward as it was made to do throughout this study. No change in amplification can correct for the error in polarity.

Thus, when the spatial axes are in the neighborhood of +30 degrees, the low values (negative here) of the central terminal potential
tend to compensate for eccentricity errors of the back electrode. When the axis and eccentricity are nearer the direction +90 degrees, the absolute value of \( V_B \) is more negative and the central terminal is less negative or actually positive, so that \( V_B-CT \) is negative and the loop is made to point forward. When the spatial axis is near -30 degrees the absolute value of \( V_B \) is so great that the loop points backward in spite of a positive value for the potential of the central terminal.

It is evident from the curves for X-Y of figures 20C and 20D that the anterior-posterior bipolar lead employed in measuring the corresponding anterior-posterior component of the vectors for the cube do not make nearly as great errors as does the back electrode for the tetrahedron as the latter is commonly employed. No error in polarity is demonstrated on the curves reproduced. Theoretically (and actually) it does occur however, when the anterior-posterior component of the spatial vector is small and/or has a very “vertical axis.”

The general character of all these phenomena will be unaltered by changing the position of the frontal plane. As indicated in figure 21, this would change the absolute values of the potential of the central terminal, but would not change the relative values at the different axes and eccentricities.

The variation of the potential of the central terminal, which must take place, but which cannot, as yet, be measured for the purposes of correction, affects all of those methods which employ the central terminal as a reference electrode. The conventional precordial leads employed clinically are probably not erroneous to a significant degree as the result of central terminal error because they are so close to the heart that the potentials are proportionately very much greater than those of the central terminal. However, some phenomena may be explainable on this basis.

On the other hand, any method which employs unipolar leads for the purpose of mathematical correlations, such as determination of the spatial axis of the mean QRS, is fallacious for this as well as for other reasons.

Furthermore, it becomes clear that attempts to derive the precordial potentials from “spatial” loops derived from oscillographic technics are unscientific. It is not within the scope of this paper to discuss all the errors in principle involved in such attempts. However, it must be pointed out that both the precordial leads and the “spatial” loops, considered mathematically, contain significant errors and that these errors are not related to one another. It is true that the errors of the central terminal are related to the Einthoven triangle, but the errors of the back potential employed in the tetrahedron, as well as the potentials of other chest leads, include errors which have no relation to the Einthoven triangle. The cube is in no way related to the central terminal. Again, too many attempts to relate the precordial potentials and potential at other points on the surface of the chest to “spatial” loops have disregarded the factor of time.

It is possible to derive the general form of the precordial leads from the “spatial” loops of the cube as well as from theoretic spatial loops derived from anatomicophysiologic considerations. This may be permissible for teaching purposes, but the errors should be pointed out when the derivation is made.

Fig. 21. The curves show the variations of the potential of the central terminal during the inscription of the QRS complex when the mean spatial QRS is at axes +90 degrees, +45 degrees and +30 degrees. The upper set of curves applies when the frontal plane is assumed to be in the anterior position; the lower set applies when it is in the midposition. The maximum potential attained, as shown on the curves, may reach 0.4 the value of the maximum theoretic limb potential found in this study, and is frequently greater than the absolute potential at one or more of the limb electrodes.
SUMMARY

A dipole was moved about in space in a manner which might be applied to electrocardiographic analysis and the effect of this movement (eccentricity) upon the manifest cardiac vector as calculated in the conventional manner was studied. The range of positions of the dipole studied rested on the assumption that the heart is generally to the left or below and to the left of the center of the Einthoven triangle.

Next, the eccentricity effects appropriate to their location in the chest and to their spatial axes were applied to the various stages of the process of accession in the ventricles as represented in the Gardberg-Ashman hypothesis, and the effect of dipole eccentricity upon the manifest QRS loop was approximated.

The theoretic potential of the central terminal was calculated for many dipole positions.

CONCLUSIONS

1. In agreement with Frank, it was found that the errors in magnitude and direction of the manifest vector produced by eccentricity of the dipole are considerable. However, these errors follow a definite order and the errors which occur as a result of dipole eccentricity may be described as systematic.

2. As applied to the QRS loop, these errors are found to cause an exaggeration of the electrical rotation of the heart. It is pointed out that the occurrence of this systematic error does not invalidate the correlations made in the past which employed the electrical rotation of the heart as a factor. It is suggested that an understanding of the eccentricity errors may make it possible to understand individual cases in which the correlation was poor.

3. The larger complexes which are seen when the mean QRS axis is +65 to +85 degrees and the smaller complexes when the mean QRS is at 0 to −30 degrees may be in part a result of eccentricity.

4. Small QRS complexes in the limb leads and therefore small, mean manifest QRS vector values, formerly attributed entirely to a larger backward direction of the mean spatial QRS, may be due to eccentricity. It is suggested that this offers an explanation for the finding of small back potentials when the mean manifest QRS axis is small.

5. It is concluded that dipole eccentricity accounts for some of the “twisted” and “folded” loops recorded by spatial vectorcardiographers.

6. A number of individual electrocardiographic problems seem to yield to analysis by application of the effects of dipole eccentricity. A few are described.

7. The potential of the central terminal varies considerably during the inscription of the QRS complex. This may account in part for the curious division of Burch’s loops into the two groups which he described. A correlation with the manifest QRS axis is made.

8. On the basis of variation of the potential of the central terminal, the value of any method which employs “unipolar” chest leads for any sort of mathematical correlation or to determine the spatial direction of the mean QRS axis is questioned. Together with other errors involved, this evidence makes it obvious that such methods are fallacious.

Again on this basis the notion that “unipolar” leads reflect the absolute potential at a point and are, therefore, more accurate than bipolar leads is questioned.

It is quite clear to the writer that he has assumed that the conducting medium is homogeneous and that it is limitless. Nonhomogeneity of the conducting medium and the limiting contours of the chest walls will, when their effects become known, modify the results found here. In the writer’s opinion these effects will modify the results and conclusions presented here more in a quantitative than in a qualitative manner.

SUMARIO ESPAÑOL

1. En conformidad con Frank, se encontró que los errores en magnitud y dirección del vector manifiesto producido por la excentricidad del dipolo son considerables. Sin embargo, estos errores siguen un orden definitivo y los errores que ocurren como resultado de excentricidad del dipolo pueden ser descritos como sistemáticos.
2. Estos errores han sido hallados causar una exageración de la rotación eléctrica del corazón cuando son aplicados al lazo del QRS. Se recalca que la ocurrencia de estos errores sistemáticos no invalida las correlaciones hechas en el pasado que empleaban la rotación eléctrica del corazón como un factor. Se sugiere que un entendimiento de los errores de excentricidad pueda hacer posible el entender casos individuales en los cuales la correlación fue pobre.

3. Los complejos mayores que se ven cuando el promedio del eje QRS es +65 a +85 grados y los complejos menores cuando el promedio de QRS está entre 0 a -30 grados puede ser en parte resultado de la excentricidad.

4. Complejos QRS pequeños en las derivaciones de las extremidades y por consiguiente pequeños, valores del promedio del vector QRS manifiesto, anteriormente atribuidos enteramente a una dirección hacia atrás mayor del promedio espacial QRS, podría ser debido a excentricidad. Se sugiere que esto ofrece una explicación para el hallazgo de potenciales pequeños en la espalda cuando el eje manifiesto QRS es pequeño.

5. Se concluye que la excentricidad de dipolo explica algunos de los lazos “torcidos” y “dobladados” registrados por los vectorcardiógrafos espaciales.

6. Un número de problemas electrocardiográficos individuales aparentaron ceder a análisis por medio de la aplicación de los efectos de excentricidad de dipolo. Unos pocos son descritos.

7. El potencial del terminal central varía considerablemente durante la inscripción del complejo QRS. Esto puede explicar en parte la curiosa división de los lazos de Burch en los dos grupos que el describió. Una correlación con el eje manifiesto QRS se hace.

8. De acuerdo al principio de variación de potencial del terminal central, el valor de cual-

quer método que emplee derivaciones precordiales “unipolares” para cualquier clase de correlación matemática o para determinar la dirección espacial del eje promedio es dudoso. Junto con otros errores envueltos, esta evidencia hace obvio que tales métodos son delusorios.

También así de acuerdo a este principio la noción de que las derivaciones “unipolares” reflejan el potencial absoluto en algún punto y son así más exactos que las derivaciones bipolares se duda.

Es bastante claro para el autor que el a asumido que el medio de conducción es homogéneo y que es ilimitado. La no homogenidad del medio conductor y los contornos límitejos de las paredes del tórax, modificaron cuando sus efectos sean conocidos los resultados encontrados en este trabajo. De acuerdo a la opinión del autor estos efectos modificaran los resultados y conclusiones presentados aquí más en una manera cuantitativa que cualitativa.

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A Theoretic Analysis of the Effects of Dipole Eccentricity upon the Manifest Vectors, the Manifest QRS Loops and the Potential of the Central Terminal
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