# Spatial Vector Electrocardiography: Method and Average Normal Vector of P, QRS, and T in Space

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In spatial vector electrocardiography the human thorax may be assumed to be a homogeneous sphere with a heart-vector-point source situated at its geometric center. Any heart vector in space may be obtained from its projection in two planes, such as the transcentrally vertical and horizontal planes. The six limb leads define the RLF plane and the six precordial leads define approximately a "horizontal" plane. Furthermore, if it is assumed that the RLF plane and the "horizontal" plane are, respectively, the transcentral vertical and horizontal planes, it is quite convenient to visualize any heart-vector* in space from corresponding polarities written in the routine 12-lead electrocardiogram, by means of lead "polarity" circles concentrically arranged in respective planes. Such an arrangement for the RLF plane from the six limb leads has been previously published by us.[1,2]

## METHOD AND ILLUSTRATION

The method is presented in Fig. 1. This figure consists of (*a*) the model, (*b*) the front view of the human thorax with electrodes R, L, F, and six limb lead "polarity" circles, and (*c*) the cross section of the human thorax with precordial electrodes 1, 2, 3, 4, 5, 6, and six precordial lead "polarity" circles. A "polarity" circle is composed of a positive semicircle (white), a negative semicircle (gray), and two zero-potential boundaries.

As can be seen from Fig. 1, *b* and *c*, the polarity circle of a lead is the geometric consequence of the Einthoven assumption. Of a bipolar lead the positive semicircle faces the positive electrode, the negative semicircle faces the negative electrode, and a line joining the two zero-potential boundaries would be perpendicular to that lead axis. Of an unipolar lead the positive semicircle faces the exploring electrode, the negative semicircle faces the Wilson central terminal or the geometric center, and a line joining the two zero-potential boundaries would be perpendicular to that lead axis. Any heart-vector that resides in the positive semicircle yields a positive deflection in that lead, any in the negative semicircle a negative deflection, and any coinciding with a zero-potential boundary a zero potential or a transitional complex.

In Fig. 1, *b* the six concentrically arranged "polarity" circles are, from within outward, those of the limb leads, I, II, III, R, L, and F, respectively. In Fig. 1, *c* the six concentrically arranged

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*Throughout this paper the term "heart-vector" is limited to direction; no magnitude is concerned.

"polarity" circles are, from within outward, those of the precordial leads, $V_{1,2,3,4,5,6}$, respectively. By such an arrangement it is evident that any heart-vector may be visualized at a glance in each plane from corresponding polarities written in six respective leads. At the periphery are given direction marks in degrees, there being 24 in each plane.

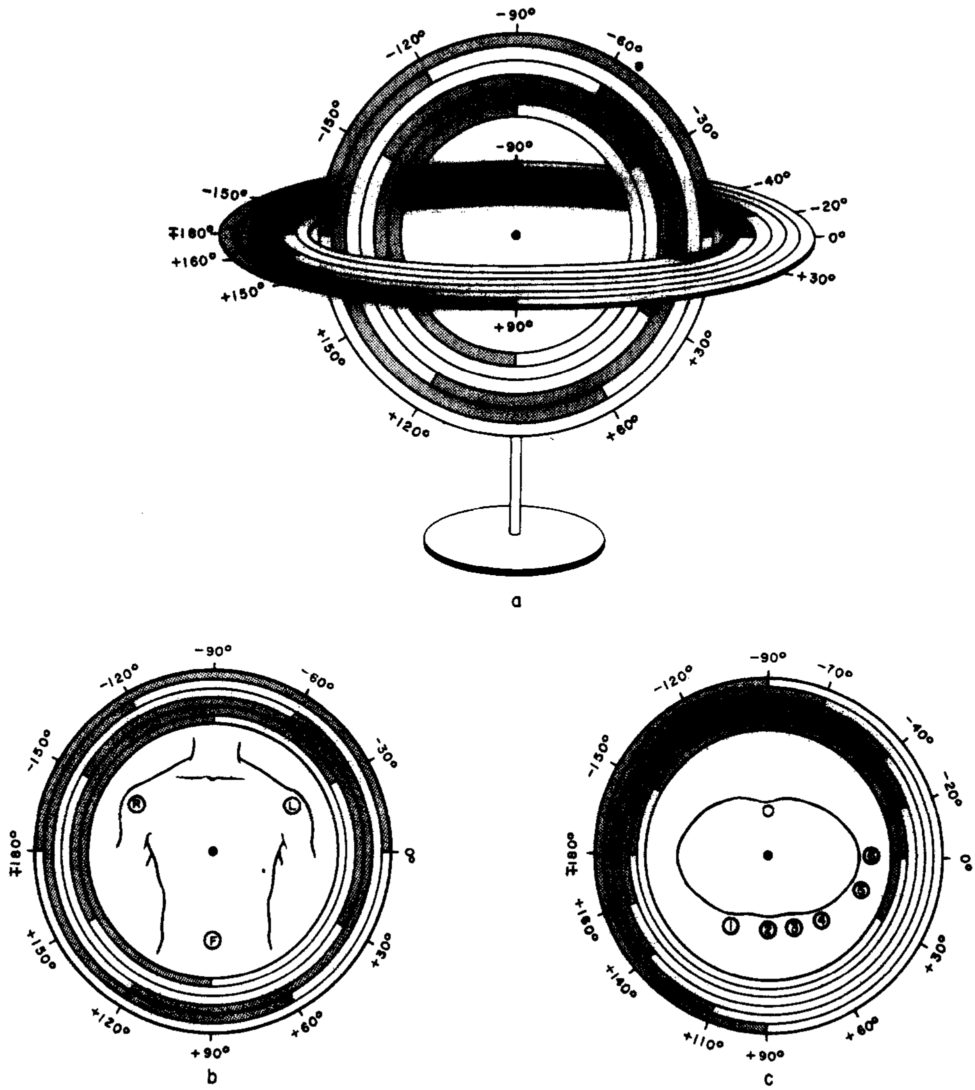


Fig. 1.—The method for spatial vector electrocardiography: *a*, the model; *b*, the RLF plane; and *c*, the "horizontal" plane.

In Fig. 1, *a* the RLF plane and the "horizontal" plane are transposed to the transcentral vertical plane and horizontal plane, respectively. The geometric center represents the heart-vector origin. Any heart-vector in space will cause a vertical plane projection and a horizontal plane projection that can be visually correlated conveniently and rapidly with corresponding polarities written in the six limb leads and in the six precordial leads, respectively, by means of "polarity" circles.

The visual correlation between the vectors of P, QRS, and T in these two planes and the corresponding area polarities written in a normal 12-lead electrocardiogram is illustrated in Fig. 2. In the RLF plane the white arrow indicates the vector of P, QRS, and T; in the "horizontal" plane the white arrow indicates the QRS vector, while the black arrow indicates the vector of P and T.

## MATERIAL AND RESULTS

Altogether, 1,000 normal electrocardiograms by the criteria of Frank N. Wilson[3] were selected at random from this laboratory for the present study. All electrocardiograms consisted of 12 routine leads (I, II, III, $aV_R$, $aV_L$, $aV_F$, $V_1$ through $V_6$), taken with a direct-writing electrocardiograph.* All patients were over 5 years of age. The vectors of P, QRS, and T were visualized in both planes from corresponding area polarities written in each electrocardiogram. The results are summarized in Table I.

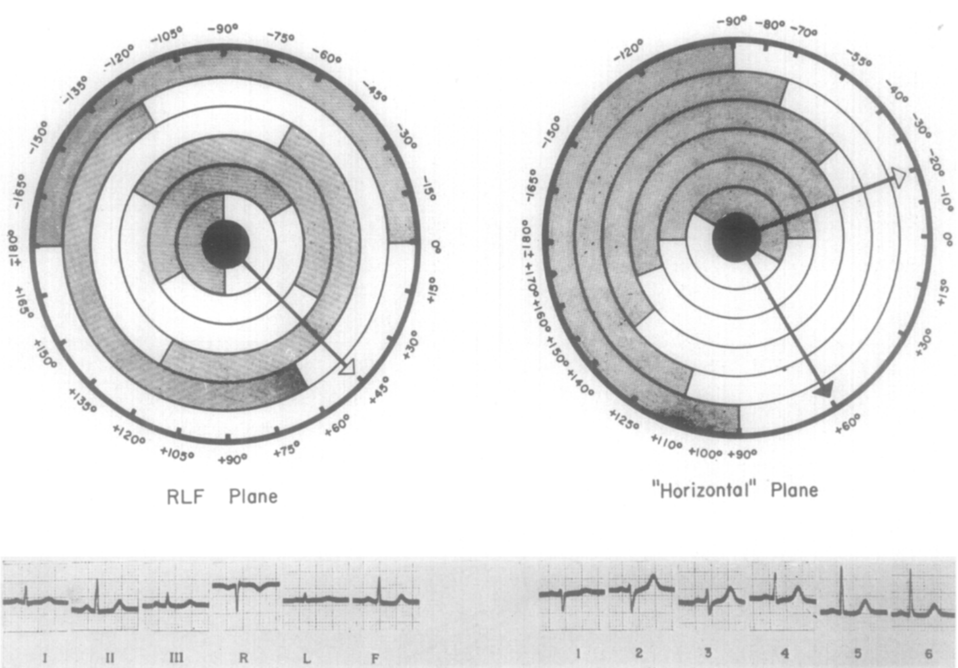


Fig. 2.—An illustration of the visual correlation between vectors of P, QRS, and T in each plane and corresponding area polarities in a normal electrocardiogram by means of the 12-lead "polarity" circles.

The incidence in per cent ($^1/_{10}$ of the actual electrocardiograms) in the various directions of the vectors of P, QRS, and T in both planes is diagrammatically illustrated in Fig. 3.

The average norm of a vector in each plane may be calculated from the formula: $(d_1p1 + d_2p_2 + d_np_n)/100$, in which d is direction, p is per cent. The results are summarized in Table II.

*Sanborn Viso-Cardiette, Sanborn Company, Waltham, Mass.

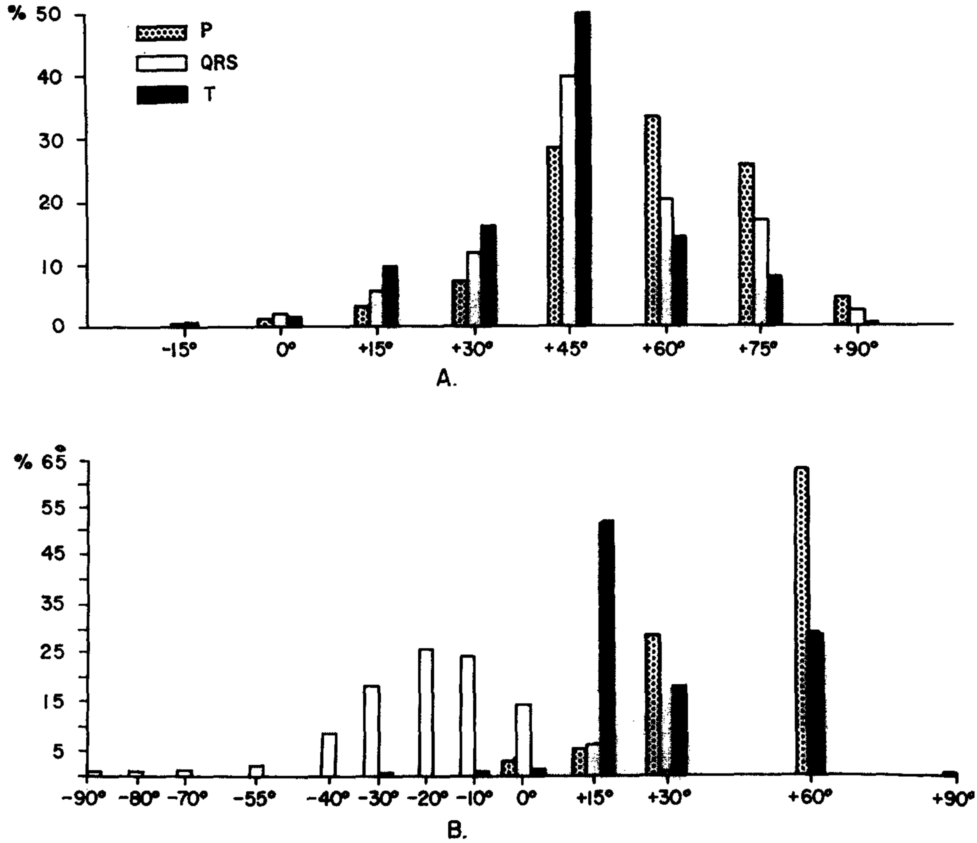


Fig. 3.—The incidence in per cent in the various directions of vectors of P, QRS, and T in the RLF plane (*A*), and in the "horizontal" plane (*B*).

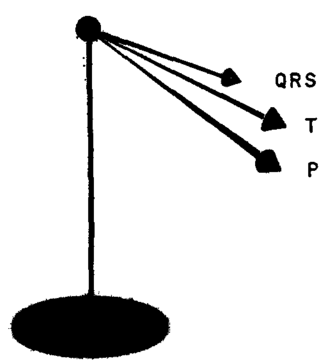


Fig. 4.—The average normal vectors of P, QRS, and T in space.

The front view of the average normal vectors of P, QRS, and T in space is illustrated in Fig. 4. They all point left and downward, P and T being directed anteriorly, and QRS, posteriorly. The angle formed by QRS and T is measured as 60 degrees. The angle formed by P and the plane defined by QRS and T is measured as 15 degrees.

TABLE I. THE INCIDENCE IN THE VARIOUS DIRECTIONS OF VECTORS OF P, QRS, AND T IN THE RLF PLANE AND IN THE "HORIZONTAL" PLANE

*RLF Plane*

| | −15° | 0° | +15° | +30° | +45° | +60° | +75° | +90° |
|---|---|---|---|---|---|---|---|---|
| P | | 12 | 36 | 74 | 286 | 332 | 255 | 5 |
| QRS | 2 | 22 | 60 | 118 | 406 | 196 | 170 | 26 |
| T | 4 | 14 | 97 | 162 | 503 | 138 | 80 | 2 |

*"Horizontal" Plane*

| | −90° | −80° | −70° | −55° | −40° | −30° | −20° | −10° | 0° | +15° | +30° | +60° | +90° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | | | | | | | | | 24 | 55 | 288 | 630 | 3 |
| QRS | 2 | 2 | 4 | 24 | 87 | 180 | 258 | 239 | 142 | 60 | 2 | | |
| T | | | | | | 1 | | 2 | 10 | 518 | 180 | 289 | |

TABLE II. THE AVERAGE NORMAL VECTORS OF P, QRS, AND T

| | RLF PLANE | "HORIZONTAL" PLANE |
|---|---|---|
| P | +55° | +48° |
| QRS | +47° | −17° |
| T | +44° | +31° |

## DISCUSSION

The underlying assumption of the present method is the spatial counterpart of the Einthoven assumption; it, too, is not consistent with real conditions. The human thorax is not a homogeneous sphere; the heart-vector is not centrally located and it is not constantly a single resultant vector as registered in the precordial leads; and the precordial leads do not lie in an absolutely horizontal plane. Real conditions may vary from individual to individual; the inaccuracy of this method, too, is not invariable. This is true of any model with similar underlying assumptions, as for example, the cylindrical model of Grant.[4] In experimental work it has been shown that the amount of inaccuracy obtained from the Einthoven assumption depends each time on its deviation from real conditions and is, indeed, not a matter of more or less careful measurements.[5-7]

The present method is found to be useful as a method for approximate spatial vector electrocardiography from 12 routine leads and in clinical teaching. The visual correlation between polarities written in the 12 routine leads and the corresponding spatial heart-vector by means of "polarity" circles presents itself as a very practical, convenient, and rapid method of analysis.

The present study is concerned only with heart-vector direction, although spatial heart-vector magnitudes may also be obtained conveniently in this model. For example, one may measure the magnitude of a given vector in limb Lead I; the line which is perpendicular to this lead axis and which cuts this magnitude will intersect the spatial direction of the vector at a point. The point will represent the tip of the spatial vector magnitude. Consequently, this model may be used to reconstruct vectorcardiographic loops in space from a routine 12-lead electrocardiogram. The other laborious or careful methods with similar underlying assumptions cannot, in fact, reduce the inaccuracy.

Real conditions being equal, the inaccuracy of such methods depends furthermore upon the heart-vector direction itself. In an earlier communication we pointed out this dependency, and demonstrated such effect in the frontal plane by means of curves transformed from the Einthoven triangle and the average Burger triangle.[8] It was found that the heart-vector direction obtained in the Einthoven triangle was more inaccurate where the curves were apart, less inaccurate where the curves drew nearer, exceptionally accurate where the curves intersected.

An important concept should be briefly pointed out, namely, spatial vector electrocardiography may be studied on a physically founded basis. By means of a manikin it is possible to obtain Burger lead vectors[9] from the 12 routine leads. It may be anticipated that, on the average, such experimental data when applied to human beings will yield results more nearly accurate than those based merely on the Einthoven assumption or its spatial counterpart. Thus, it seems likely that more nearly accurate spatial vector electrocardiography will be achieved in the near future.

Proper electrode combinations through definite, unequal resistances based on lead-vector data would make it possible to obtain six limb lead vectors in the vertical plane and six precordial lead vectors in the horizontal plane in functional angulation of 30 degrees to each other. This is similar in principle to the functional orthogonalization of vectorcardiographic systems, such as proposed by Schmitt and associates,[10] by Frank,[11] and by us.[12]

In taking the corrected 12-lead electrocardiogram the resistance assembly previously constructed may be inserted between the patient and the electrocardiograph while the electrodes on the patient remain at routine limb and chest positions. The present model (Fig. 1, *a*) may be used for the same purpose after a slight constructive adaptation is made so that a line joining the two zero-potential boundaries of a "polarity" circle will be perpendicular to the same lead vector. We are undertaking this study.

SUMMARY

A method for spatial vector electrocardiography from 12 routine leads by means of a model is described. It is found to be useful as a practical method for quick and approximate determination and in clinical teaching.

Presented are the average normal spatial vectors of P, QRS, and T obtained in this model from 1,000 electrocardiograms classified as normal under the criteria of F. N. Wilson. The average normal vectors of P, QRS, and T in space are directed to the left and downward, P and T being directed anteriorly, and QRS, posteriorly. The angle between QRS and T was 60 degrees; the angle between P and the plane defined by QRS and T was 15 degrees.

The problems of the spatial counterpart of the Einthoven assumption is discussed on the basis of previous experimental work.

It is anticipated that spatial vector electrocardiography may be studied on a physically founded basis by means of the Burger lead-vector concept while the electrodes on the patient remain at the routine 12-lead positions. On the average this will give more nearly accurate results than those based on the spatial counterpart of the Einthoven assumption. The present model may be adapted easily in such study for convenient visual correlation as described above.

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