Comparison of Spatial Instantaneous ECG Vectors, Measured with the SVEC, with Mean Vectors Derived from Conventional ECG Leads

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Two approaches to the analysis of spatial electrocardiographic vectors are currently being used: construction from the conventional ECG leads, and measurements from oscilloscopic recordings of spatial loops. There are several fundamental differences between the approaches, and there is no a priori certainty that equivalent or even similar phenomena are being investigated. This study presents a statistical comparison between mean spatial vectors, constructed from the conventional ECG, and instantaneous maximum spatial vectors, determined with the stereovector electro-cardiographic technic.

Two different approaches are in use for characterization of spatial ECG vectors: construction based on conventional ECG data, and direct oscilloscopic recording of spatial loops by means of the stereovector electrocardiograph (SVEC) or related methods. Both approaches assume the general validity of the dipole theory for interpretation of surface potentials. Because of well-known complicating factors, complete accord with simply interpreted dipole theory cannot be expected. It has been largely a matter of individual interpretation whether the degree of agreement or of disagreement with the dipole theory was emphasized. This explains to some extent the large and controversial literature which has arisen on this issue. In a quantitative test utilizing a mirror pattern cancellation technic we found that in an average normal person or patient about 90 per cent of the total potentials in any of numerous electrode locations can be associated with a simple central dipole (vector), and only 10 per cent to residual components including local patterns. These results, which are in good agreement with Schaefer’s work, justify the interpretation of surface potentials in terms of spatial vectors, as a working approximation.

While there is a common basis for the two approaches, there are also important differences. Duchosal and Sulzer, and Scherlis and coworkers found good agreement between scalar precordial ECG's actually recorded and those constructed from spatial loop oscillograms. This agreement is, however, at best qualitative, since only contours were compared. Polzer and Schuhfried found remarkably different contours and orientation for the oscilloscopically recorded spatial loops when they tried successively on the same patients five different, but presumably equivalent, systems of electrode placement as suggested by various authors. This experimental variation of patterns makes it obvious that we must not expect, except by rare chance, that the oscilloscopically recorded loops obtained with one lead system will correspond identically with the vectorial reconstructions built up from data obtained from different lead sets. At the present time there appears to be no clearly established superiority or inferiority of one or the other method of electrode placement presently in use for spatial loop recording. Perhaps the discrepancies between methods are...
not more obvious because only essentially qualitative interpretations have thus far been undertaken. It appears, therefore, that the question of agreement between spatial vectors constructed from conventional leads and those determined from oscilloscopic records is still unsettled.

We are concerned in this study with correlations between spatial vector features obtainable using conventional leads and conventional equipment exclusively, and those obtained with our SVEC equipment utilizing the partially orthogonalized lead systems which we have temporarily adopted on the basis of preliminary experiments. We must therefore expect differences due to the fundamentally different vector components being measured in addition to those resulting from the different measures of vector amplitude and orientation used in the two systems. Any correlations which we find, must exist in spite of these recognized sources of difference. The nature and degree of such correlations consequently are pertinent in any considerations as to the validity, practical applicability, and limitations of spatial vector analysis. As a background for the discussion of our results, a condensed description of the methods we have used and their theoretical implications will be given in the following discussion.

Construction of a mean vector was attempted by the pioneer workers Einthoven, De Waart, and Fahr, but, of course limited to the frontal plane. The authors were aware that the several phases of the QRS and T loop are projected differently on the different standard leads, depending upon the contours of the loops. The discrepancies are less obvious for narrow loops, and increase as the loop widens. The method becomes more meaningful when instantaneous vectors are constructed from instantaneous leads, as shown by the same authors. While the contour of the loop can be constructed from a number of instantaneous vectors, this has rarely been done. The development of high-speed oscilloscopic technique has actually eliminated the need for these tedious and time consuming procedures.

Only by elimination of all but a few vector components, which are taken as representative, is it practically possible to accomplish useful vector analysis using conventional ECG data. This situation is actually not drastically different for the quantitative analysis of oscilloscopic records of spatial loops, as will be discussed later.

Einthoven, De Waart, and Fahr's "manifest potential" is a mean frontal plane vector measure which seems to be fairly representative of the general direction and magnitude of the electrical equivalent dipole currents near the time of their maximum. In view of the phase differences in the three standard leads, such a "mean vector," however, does not necessarily exist at any one time. The inadequacy of the frontal plane leads in detecting sagittal electrical current components was first shown by the use of precordial leads in anterior wall myocardial infarct, although at that time this was an empirical development without any attempt at analysis of spatial vectors. This demonstrated, however, the need for precordial leads and the need to analyze spatial vectors instead of frontal plane vectors alone. Spatial vectors can be constructed from their projections on the frontal (standard leads) plane and the horizontal (precordial leads) plane. Grant determined a direction in the horizontal plane from the estimated null-point, which he defined as the location of equiphasic or isoelectric potentials. While the T wave may give an essentially isoelectric projection, this is never the case for the entire QRS complex. The estimate of the null point from equiphasic potentials is an approximation which is not strictly valid, since the R and the S waves are projections of different parts of the spatial loop. In using the precordially located equiphasic potential for determining the direction of a horizontal plane "mean vector" it is implicitly assumed that the frontal plane mean vector and the horizontal plane mean vector are isochronous and equivalent. This is not necessarily the case. The degree of equivalence or the discrepancy will depend upon the orientation of the loop and its spatial orientation, on the chest configuration, etc. A qualitative analysis of spatial vectors has been made from the distribution of "null contours," that is, equiphasic potentials, on the surface of the chest. This approach requires numerous chest leads. In some similar work on early right ventricular preponderance we used at least 36 such leads. Since this method requires so many leads and is subject to the same lack of null synchrony, it is not practical for routine clinical use.

The prevalent use of bi-polar derivation for the standard leads in combination with central-terminal-referred leads for the precordial components is also not unimportant. The Wilson terminal is, at best, only relatively neutral as a reference electrode for the frontal plane leads, but is not adequate for the precordial lead reference. It has been recognized for some time that the Wilson terminal is not "neutral," and more pertinent quantitative information has recently been obtained. The use of V leads, therefore, must be expected to contribute to the discrepancies in vectors determined from the
standard and precordial V leads. A considerable amount of attention has been paid in recent years to these and other problems of lead geometry. Both the model and theoretical approaches have been used by such investigators as Frank,19 McFee and Johnston,17 and Burger and van Milaan.18

The analysis of spatial vectors from conventional leads in Grant’s work has been essentially qualitative and limited to the general direction of mean spatial vectors. One might feel that any quantitative analysis is unwarranted in view of the approximate nature of a mean spatial vector, but adoption of this view would require one to forego the real advantages of even a semiquantitative distinction between normal and abnormal conditions and among various abnormal conditions. In the present paper we shall attempt to resolve this question by comparing the results of a new semiquantitative method of analysis from conventional lead data19 with the corresponding quantities obtained from a direct instantaneous spatial vector recording method.20-21

**Method I**

**Analysis of Spatial Vectors From the Conventional ECG.** In this method the mean vector directions are expressed in terms of the azimuth (H°) and elevation (V°) angles for both the QRS and the T complexes. The magnitude (Mag.) of each complex is also determined, and the angle between the vectors is separately specified even though it is implicit in the other data. These spatial vectors are geometrically constructed with the aid of a simple mechanical analyzer, I. The vector projections in the horizontal plane are found from the “null points” in precordial leads. The vector projections in the frontal plane are found from the standard leads by means of a modified Einthoven procedure. Taking magnitude from Lead I, which is a distant lead common to both planes, and obtaining azimuth and elevation from the projections, the spatial vector is easily resynthesized.

Despite the approximate nature of this procedure, we expected that a significant differentiation between normals and abnormals would be possible within the experimentally determined limits of variability. Actually a significant differentiation was found not only between normals and abnormals, but also between several normal variables such as body weight, age, exercise.22 This demonstrates that the approach, in spite of its limitations, is superior to the conventional analysis of scalar ECG’s which ignores all spatial characteristics.

**Method II**

**SVEC Analysis of Instantaneous Spatial Vector Traces.** It is the purpose of the SVEC method18-20 to portray quantitatively, and measurably, on a set of two cathode ray tubes a three-dimensional stereoscopic image of the electrocardiographic spatial vector trace for photographic recording or for direct visual observation. This purpose is best accom-

ished through electronic computation of a set of three nominally orthogonal and normalized vector heart components representing respectively the X or horizontal, the Y or vertical, and the Z or sagittal component from any three different electrocardiographic leads.

These orthogonalized components, however obtained, are run through a resolver which electronically recomputes the voltage data so as to convert it from a simple frontal view into the chest, to a mathematically exact equivalent view toward the heart center from any chosen azimuth as set on one dial and any chosen elevation as set on another. Such a rotation of coordinates permits best possible viewing of any chosen feature of the SVEC complexes and permits exact determination of the spatial orientation of any features through alignment of those features with a prime visual coordinate.

The stereoscopic picture as viewed on the cathode ray screen is built up electronically by optical superposition in the two eye fields of two different patterns which represent the respective pictures which the individual eyes would see if looking at a three-dimensional graph of the vector data. The computer changes the relationship between the two cathode ray spots visible at each instant with reference to a fixed illuminated graticule seen by both eyes so that only by perceiving the spot as being at one particular spatial position can the eyes rationalize the image they see. In this manner the entire vector trace is scanned out spatially, and through persistence of vision is seen as a pattern of three space loops representing the principal ECG complexes. From the resolver on, the SVEC computer presents electrically an accurate visual image of whatever three-dimensional vector voltage data is supplied to it, irrespective of the source of such data. However, the synthesis of the data for use in the computer from chest and other leads is not unambiguously related to the theory of potential distribution in the body. The resulting picture will depend on the lead locations and the weighing and adjusting process governed by the particular theoretical convictions of the experimenter. We, therefore, think of the SVEC system as comprising two parts: first an accurate spatial presentation system for whatever X, Y, Z, data is supplied to it, and second, a weighing and normalizing system which supplies these adjusted data from the raw lead voltages.

This latter process has been accomplished with varying degrees of approximation by different investigators. Some have made the very crude supposition that electric vector components will be found along any lines parallel to the anatomical X, Y, Z, axes. Others have used the somewhat better approximation that dipole theory for a fluid sphere may safely be employed. Hardly any have attempted to normalize the components to correct for electrical distance and body inhomogeneities.

At the present time we are well aware that a good
lead system with properly determined mixing coefficients is possible and are actively seeking such a lead set with the aid of plastic torso models and a feedback coefficient synthesizer; but in order to get usable data over the past three years while such experiments have been developing, we have standardized on an interim arrangement of leads which was empirically determined to approximate orthogonality and which is not severely distorted. Here the leads themselves are used as the heart vector components in a first approximation to the more exact values which a properly designed weighing and mixing computer will ultimately provide.

The present system utilizes the following bipolar leads: a transverse lead with the electrodes about 2 cm. forward of the left and right midaxillary lines and at the level of the fourth intercostal space at the sternum, the pair constituting the X lead; a vertical lead with one electrode on the forehead and one on the left leg, the pair constituting the Y lead; and a sagittal lead with the chest electrode 2 cm. to the right of the sternum at the fifth intercostal space, and the back electrode directly behind the chest electrode, the pair constituting the Z lead. Considering positive potential components on the patient as those which make the left side, the head, or the chest electrode positive, these conventions result with normal right-handed presentation coordinates in respective deflections toward the observer's right, upward, and toward the observer for positive component changes. Thus the pattern obtained with the resolver set at azimuth zero, elevation zero corresponds to the actual directions and magnitudes of the heart's electric (positive) "vector" during the heart beat as visualized by the observer having a frontal view of the subject. By means of the resolving computer, the observer may change his point of view with respect to the subject's pattern without moving the electrodes. One dial changes the azimuth view as if the observer's position were being rotated about a vertical axis in the subject. Azimuth angles are indicated on a continuously variable scale in the following manner: zero degrees, front; 90°, left side; 180°, back; and 270°, right side. A second dial controls the observer's effective elevation. Positive angles indicate a superior view and negative angles an inferior view with respect to the level of the subject's heart. Elevation in readings range from —90° (foot view) through zero degrees (level view) to +90° (head view). When the pattern is rotated so that the major axis (or, for that matter, any instantaneous axis) points directly toward the observer, the azimuth and elevation dials then read the orientation angles in space for that axis. Thus no computation is required to obtain these values, which may be read to an accuracy of about ±1 degree and which may be reproduced by different observers with a probable error of not over 4 degrees.

The QRS axis orientation is obtained by using the azimuth control to rotate the pattern from its frontal view position to one in which the axis is straight down, in the viewer's field. The pattern is then rotated by means of the elevation control until the axis is directed toward the observer. The orientation angles are now read from the azimuth and elevation dials. The pattern is next rotated from this minimum projection position through +90 degrees by means of the elevation control so that it is now seen at its maximum projection. This flat pattern is photographed, and the amplitude of the axis read off on the calibrated reticule in the field of the pattern. The procedure is then repeated for the T maximum axis. Figure 1 a to d shows the sequence of patterns for a typical case in which the QRS major axis is being determined.

In the present study it is the spatial vector trace

![Diagram of QRS loop orientation](http://circres.ahajournals.org/content/33/4/323/F1.large.jpg)
built up from the X, Y, Z, components described which we are comparing with the equiphasic-null-derived vector of method I to determine whether a close correlation exists and consequently whether data derived from the first type of measurement can be interpreted as nearly equivalent to that obtained by the more exact electronically computed data. This correlation is not only of theoretical interest but is of practical interest for it determines whether the null obtained without elaborate instrumentation can, with a little labor, be converted into data otherwise obtainable only with the SVEC computer or its equivalent.

Experimental Group. The SVEC and the conventional ECG were taken on 48 normal middle-aged men between 50 and 60 years. This was done in 1953 and repeated in 1954. All men were members of a larger experimental group and have been under observation in five consecutive years (1948-1953). In addition to a thorough clinical examination, numerous laboratory tests were applied including response to various physiological stress situations in the annual check-ups. No evidence of pathology was found in any of these subjects, and all histories were negative. The criteria for normal conditions therefore were more rigid than is usually the case.

RESULTS

Different coordinate conventions were originally used in the conventional ECG measurements (method I) from those adopted for the SVEC measurements (method II). Consequently, for comparison of the two methods, the values of method I were recalculated and expressed in terms of method II conventions.

The angle (\( \Delta A^\circ \)) between the maximum as well as the mean spatial QRS and T vectors was measured with the mechanical analyzer previously mentioned. Group mean values for the axis orientation angles and magnitudes of the mean vector (method I) and maximum vector (method II) were calculated separately for 1953 and 1954. Corresponding individual standard deviations were also calculated. There was no significant time change in the group means or in the standard deviations for any of the items. We then calculated the individual averages for the two repeat determinations in order to obtain a more reliable set of values for each subject, and table 1 lists the means (M) and standard deviations (S.D.) of these values. The differences between the SVEC and ECG means (row 5) were statistically significant in all items (t values, row 6), but they were comparatively small for the QRS azimuth and the T elevation angles. Even the larger differences of 16° each in QRS-elevation and in T-azimuth are relatively small as compared to the large mean differences found between normal groups and groups of patients, as measured by either one of the methods. Both QRS and T elevation were more negative (i.e., point more downward) for the mean spatial vectors (method I) than for the maximum vectors (method II). It was expected that the mean spatial vectors would be smaller than the corresponding SVEC maximum vectors, but it was somewhat surprising to find them

<table>
<thead>
<tr>
<th>Method</th>
<th>QRS</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Az ( \circ )</td>
<td>EL ( \circ )</td>
</tr>
<tr>
<td>I (ECG) M</td>
<td>115</td>
<td>-39</td>
</tr>
<tr>
<td>S.D.</td>
<td>19.6</td>
<td>26.3</td>
</tr>
<tr>
<td>II (SVEC) M</td>
<td>106</td>
<td>-23</td>
</tr>
<tr>
<td>S.D.</td>
<td>16.7</td>
<td>12.5</td>
</tr>
<tr>
<td>Diff. I-II M</td>
<td>+9</td>
<td>-16</td>
</tr>
<tr>
<td>t</td>
<td>2.35</td>
<td>(3.82)</td>
</tr>
<tr>
<td>F</td>
<td>1.38</td>
<td>4.43</td>
</tr>
<tr>
<td>r</td>
<td>0.432</td>
<td>0.893</td>
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</table>

Means (M) and standard deviations (S.D.) of azimuth (Az.), elevation (El.), magnitude (Mag) of the mean (method I, conventional ECG) and the maximum spatial QRS and T vectors (method II, SVEC), and the angle between both vectors (\( \Delta A^\circ \)) in 48 normal men. Average of two measurements (1953 and 1954). Statistical significance of t for the differences between the means: P .01 = 2.64; P .05 = 1.99. Statistical significance of F for the differences between the S.D., P .01 = 1.99; P .05 = 1.53. Statistical significance of correlation coefficient r for P' .01 = .368.
less than half as large. It is possible that this difference not only arises out of the different definitions of the maximum and the mean vector, but may also be due in part to the potentials in the region of V_{2} which contribute to SVEC measurements to a larger extent than they do to the mean vector readings.

The S.D.'s for the QRS-azimuth were not significantly different in the two methods (F test, row 7). This was also true for T-azimuth and dA°. Since the t-test for significance of difference between means (row 5, 6) is strictly valid only for population groups with similar S.D.'s, the t-values for the other items are only indicative. The very high values of t for QRS-Mag and T-Mag undoubtedly express statistical significance, however. The standard deviation of the elevation was significantly greater for the mean spatial QRS and T vectors (method I) than for the SVEC maximum vectors. Although the standard deviations for the magnitudes of both QRS and T vectors were numerically smaller for method I, the standard deviations were proportionally smaller in method II, because of the larger magnitudes measured in the second method.

Figure 2 compares on a set of polar scales the angular distribution of individual results by the two methods for QRS and T azimuth and for QRS and T elevation. SVEC results are plotted inward and mean null vectors results outward from a common reference circle.
### Table 2

<table>
<thead>
<tr>
<th>Method</th>
<th>Year</th>
<th>M (S.D.)</th>
<th>QRS El.</th>
<th>T El.</th>
<th>dA°</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (ECG) 1953</td>
<td>M</td>
<td>115</td>
<td>-40</td>
<td>6.6</td>
<td>48</td>
</tr>
<tr>
<td>1954</td>
<td>M</td>
<td>114</td>
<td>-39</td>
<td>6.9</td>
<td>49</td>
</tr>
<tr>
<td>II (SVEC) 1953</td>
<td>M</td>
<td>106</td>
<td>-22</td>
<td>2.1</td>
<td>61</td>
</tr>
<tr>
<td>1954</td>
<td>M</td>
<td>106</td>
<td>-24</td>
<td>2.2</td>
<td>65</td>
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<tr>
<td>I (ECG) 1953</td>
<td>S.D.</td>
<td>0.8</td>
<td>24.5</td>
<td>0.32</td>
<td>12.5</td>
</tr>
<tr>
<td>1954</td>
<td>S.D.</td>
<td>1.1</td>
<td>1.1</td>
<td>1.0</td>
<td>1.2</td>
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<tr>
<td>F</td>
<td>1.11</td>
<td>1.01</td>
<td>0.01</td>
<td>1.1</td>
<td>1.25</td>
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<tr>
<td>II (SVEC) 1953</td>
<td>S.D.</td>
<td>16.6</td>
<td>12.0</td>
<td>0.45</td>
<td>12.3</td>
</tr>
<tr>
<td>1954</td>
<td>S.D.</td>
<td>16.7</td>
<td>13.3</td>
<td>0.44</td>
<td>12.6</td>
</tr>
<tr>
<td>F</td>
<td>1.43</td>
<td>1.07</td>
<td>0.01</td>
<td>1.20</td>
<td>1.56</td>
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</table>

Means (M) and standard deviations (S.D.) of mean (method I) and maximum (method II) spatial vectors of 48 normal men in two determinations (1953 and 1954). Statistical significance of F for difference between the S.D. for P 0.01 = 1.99; P 0.05 = 1.63.

Means for each distribution are indicated by arrows. It is evident that the distributions are all basically similar but that the means are quite significantly different in the case of the QRS elevation and T azimuth and that the distributions are noticeably different in breadth for some of the items, for example the QRS elevation.

### Table 3

<table>
<thead>
<tr>
<th>Method</th>
<th>Year</th>
<th>M (S.D.)</th>
<th>QRS El.</th>
<th>T El.</th>
<th>dA°</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>S.D.</td>
<td>10.6</td>
<td>13.3</td>
<td>0.10</td>
<td>8.9</td>
</tr>
<tr>
<td>II</td>
<td>S.D.</td>
<td>0.9</td>
<td>7.5</td>
<td>0.27</td>
<td>12.0</td>
</tr>
<tr>
<td>F</td>
<td>1.15</td>
<td>3.14</td>
<td>1.81</td>
<td>3.01</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Annual repeat variability of the mean (method I) and maximum spatial QRS and T vector (method II), expressed as standard deviations of the individual differences, in two repeats on 48 normal men, separated by an interval of one year. Statistical significance of F for P 0.01 = 1.99; P 0.05 = 1.63.

Table 2 shows the means and the S.D.'s separately for 1953 and 1954. The group means were essentially the same for the two years, and differences were not statistically significant except for T-azimuth of method II. The S.D.'s did not vary significantly.

Table 3 shows the repeat variability expressed as S.D. of the individual differences in the 1953 and 1954 determinations. The repeat variability was substantially the same in

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**Fig. 3.** Scatter diagrams of directional angles of mean QRS and T vectors (method I, ordinate) versus maximum QRS and T vectors (method II, abscissa).
both methods for QRS azimuth and for $\Delta a^\circ$, it was significantly greater for QRS and T elevation in method I, and for T azimuth, QRS and T Mag in method II. It appears that with respect to repeat variability there is no consistent superiority of one or the other method.

The correlations between the mean (method I) and the maximum (method II) vectors is illustrated by a set of scatter diagrams in figure 3 for the direction angles (azimuth, elevation) and as correlation coefficients, $r$, in the last row of Table 1 for all seven items. The correlation was highly significant statistically, exceeding the one per cent level, for all items. The highest correlation coefficient was obtained for the QRS-elevation ($r = 0.893$).

If in methods I and II identical phenomena were being measured by fully equivalent procedures, each best line in the scatter diagrams of Figure 3 would have an inclination of 45° and pass through the origin (zero on both ECG and SVEC axes). Since the slopes deviate appreciably from 45° in all cases, and since the intercepts are different from zero, at least in the case of the QRS azimuth, it is evident that the two methods of measurement differ more than statistically.

**DISCUSSION**

A central problem of spatial vector electrocardiography is that of defining a set of directions and magnitudes which will correctly characterize the principal electrocardiographic complexes. These “vector” quantities which presumably represent the P, the QRS, and the T complexes can be arrived at in numerous different ways using various combinations of experimental data and theoretical concepts. We must expect the results obtained on one individual by different methods to differ for four reasons: (1) there will be an experimental uncertainty error in each measurement, (2) the vector components used to reconstruct the total vector may be non-equivalent, (3) the methods may emphasize differently the details of the averaging process by which a single vector is made to represent all of the contributions from various parts of the heart at each instant, and (4) the propagation of systematic errors through the reconstruction process by which the total vectors are synthesized may introduce deviations.

In this study we have made measurements on a fairly large group of normal individuals by two methods which differ in most of the above particulars to learn whether, in spite of widely different experimental procedures and theoretical detail, comparable results can be obtained. Specifically, we wished to determine whether a statistical correlation existed between the two methods and whether this correlation would be high enough to allow prediction of individual results from one method to the other. Such a predictive relationship, if found, would obviously encourage use of the simpler method.

In order to determine the inherent experimental uncertainties in each method, repeat determinations were run and their internal consistency measured. Both methods were highly reproducible and were comparable in precision, so that the large differences found must be attributed mainly to factors 2 and 3 above. These should therefore be considered in somewhat more detail.

Method I makes several assumptions which are not required in method II and which can therefore cause differences: (a) the unipolar lead referred to a Wilson terminal is equivalent to a geometrically similar bipolar lead, (b) the maximal and the minimal values of each unipolar potential component are simultaneous, (c) the maximal vector component is directed perpendicular to the direction at which an equiphasic minimum is found. In addition it should be pointed out that both methods neglect normalization procedures which could compensate for varying electrical proximity to the heart and neither method is able to correct for quadrupole and higher terms which represent the deviations from dipole theory which must exist for a heart of finite size. These additional factors introduce errors which are not necessarily equal in the two methods.

The significant deviation in mean amplitudes and absolute mean vector angles points to a fundamental difference between the two sets of vector components used. From this we must conclude that the methods are not interchangeable. Much of the difference is no doubt charge-
able to the non-ideal unipolar components measured with reference to a Wilson central terminal but some must be attributed to the geometrical difference between the normal vector direction and its perpendicular as determined from equiphasic minima.

As the measurements by the two methods show a high degree of statistical correlation on a group basis we must conclude that they are related fundamentally. The correlation is not high enough to predict the more accurate information, as obtained with the SVEC, from the more approximate data of method I, but construction of the mean vector from the conventional ECG as a first approximation is justified.

The statistically significant correlation between methods I and II, also has some bearing on the general validity of spatial vector analysis for electrocardiographic interpretation. If, as postulated by the proponents of “unipolar electrocardiography,” single unipolar leads record primarily local events, no correlation could be expected for the construction of spatial vectors by methods so different as those compared in this study. Therefore, the correlation is in general agreement with the results of the dipole theory validity tests using mirror pattern cancellations.

It is our hope that in a future communication comparable measurements can be reported where identical leads are used. This approach will eliminate differences inherent in central terminals and lead geometry and will leave primarily the differences due to the equiphasic mean null.

**Summary**

Two quite different methods for measuring the principal spatial vector electrocardiographic complexes are tested by direct comparison of results on a group of 48 normal men in two consecutive annual investigations.

In the first method the vectors are constructed from conventional ECG leads with the aid of a simple mechanical vector synthesizer. A frontal plane vector projection, obtained by conventional Einthoven technic, is combined with a mean equiphasic null direction in the horizontal plane as determined from precordial leads referred to a standard Wilson terminal.

In the second method spatial vector loops are viewed directly in a stereoscopic space with the aid of the SVEC computer, and the magnitudes and directions of the maximum QRS and T vectors are read off directly.

Results obtained by either method are highly reproducible individually and form in each case a typical population of values distributed over a large solid angle. The annual repeat variability is similar in both methods and substantially larger than the immediate repeat variability.

The mean values of the spatial orientation angles and the vector amplitudes are statistically quite different by the two methods, but there is statistically a highly significant correlation between the two sets of values.

It is concluded that one should consider the spatial vector built up from equiphasic mean null precordial direction and Einthoven frontal vector as closely related but not equivalent to, and not individually predictable from the maximum SVEC spatial vector.

**REFERENCES**

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