A Study of the Relationship between Unipolar Leads and Spatial Vectorcardiograms, Using the Panoramic Vectorcardiograph

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The extent to which precordial and other unipolar leads are influenced by the proximity of the exploring electrode to one part or another of the heart is the subject of considerable debate. One approach to the problem is to determine how closely precordial leads can be predicted from spatial vectorcardiograms recorded by leads relatively remote from the heart. The panoramic vectorcardiograph described below provides a convenient way of doing this, since it automatically records scalar derivations from the vectorcardiogram for any spatial axis. Results indicate that local effects are not the predominant factor in determining the form of the complexes in precordial leads.

Although "unipolar" chest and extremity leads are now widely used in clinical electrocardiography, there is still considerable diversity of opinion about just what part of the electrical activity of the heart is recorded by such leads. Two more or less conflicting theories have been proposed: (1) that unipolar leads are "semidirect" leads, influenced principally by the electrical state of the myocardium underlying the exploring electrode, (2) that they represent summations of the electrical activity in all parts of the heart.

The first theory was introduced by Wilson and his co-workers,[11, 12] on the basis of experiments in dogs which showed that the complexes recorded by unipolar leads from the chest wall closely resembled those recorded by direct unipolar leads from the underlying epicardial surface. They concluded that unipolar leads provided a way of isolating to some extent the electrical activity of different parts of the heart. This theory has been widely accepted in the current literature, and has been used in clinical electrocardiography as the basis for the concept of "electrical position of the heart,"[12] and in the electrocardiographic determination of anatomic position and rotation of the heart.[4]

The second theory is essentially that employed by Einthoven in his calculation of mean electrical axes from the standard extremity leads.[3] Einthoven's hypothesis included only the frontal plane, but Duchosal and Sulzer,[1] as a result of their work in spatial vectorcardiography, concluded that this hypothesis was valid for any plane, and for any lead on the body surface. According to this view, the complex spread of electrical activity through the heart can be represented at any instant as a single equivalent dipole, and the voltage recorded by a precordial or other lead will be determined by the relation between the axis of the lead and the axis of the dipole, as well as the distance between the lead electrodes and the dipole. Since the spatial vectorcardiogram is a record of the variations in potential and direction of this single equivalent dipole, the form of the complexes in a precordial lead depends on the angle from which the lead "views," so to speak, the spatial vectorcardiogram. If this hypothesis is true, then it should be possible to predict the precordial electrocardiogram from a properly recorded spatial vectorcardiogram. Duchosal found it possible to do this in most cases, although there were occasional marked discrepancies.[3]

Although any complex electrical generator resembles a single dipole source when viewed from a sufficiently great distance, it has been generally supposed that precordial leads were too close to the heart for the Einthoven hypothesis to apply. Duchosal's results suggested

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that this may not be true, and that further investigation was indicated.

The comparison of the electrocardiograms actually recorded from the precordium with the complexes predicted from the spatial vectorcardiogram. The nullpoint to thoracic areas deflections, scalar plotted field the is shown as heavy line, and the T loop has been omitted. The heavy line through the nullpoint at right angles to the +60 degree axis divides the electrical field into areas of positivity and negativity for this particular axis. The parts of the vectorcardiogram which lie in the positive half of the field will be recorded by a scalar unipolar lead along this axis as positive deflections, and those parts in the negative half of the field as negative deflections. The scalar QRS complex which would be expected at the point where the +60 degree axis intersects the chest wall can therefore be plotted as shown in C.

Cardiogram is a good method of testing these hypotheses, for if the precordial leads are dominated by local effects, these local characteristics should not be apparent in the relatively remote leads from which the vectorcardiogram is recorded. The complexes predicted for the precordial area from the spatial vectorcardiogram would then differ from those actually recorded by precordial leads. In practice, however, this approach presents several difficulties. First, in order to predict from the vectorcardiogram the variations in potential at a given point it is necessary to define the spatial position of that point with respect to the nullpoint of the vectorcardiogram, that is, with respect to the electrical nullpoint in the body. Although the postulated existence of an electrical zero point in the body is a useful theoretic concept, the criteria for establishing its anatomic position are open to question, and most investigators have resorted to some arbitrary location such as the center of the ventricular mass determined radiologically.

Second, since the spatial vectorcardiogram is usually recorded in terms of its projection on three planes (frontal, sagittal, and transverse), it is possible to calculate the predicted electrocardiograms only for points which lie in these planes. For all other points either measurements on a three-dimensional model of the spatial vectorcardiogram, or lengthy mathematic calculations, are needed.

Third, the accurate calculation of predicted potential variations from even a plane vectorcardiogram is an exacting and time-consuming operation. The method is discussed in detail by Duchosal, and an example is given in figure 1, which shows the relationship between a transverse plane vectorcardiogram and the scalar* electrocardiogram to be expected in a specified direction in the electrical field.

To overcome some of these difficulties, we have adopted a method described by Schmitt in 1947 for the cathode-ray presentation of three-dimensional data. His paper presents the mathematic transformations needed to convert three-dimensional data into any desired plane projection, and shows that this can be accomplished electrically by the use of sine-cosine potentiometers. These are simply rotat-

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* The term "scalar" is used to distinguish conventional electrocardiograms, which measure the magnitude of the potential difference between two electrodes, from vectorcardiograms, which deal with spatial direction as well as magnitude.
ing variable resistors, which attenuate the voltages reaching them proportionately to the sine or cosine of the angle through which they are rotated.

Using the principles he outlined, we have designed an instrument, shown in figure 2, which makes it possible to display on a cathode ray oscilloscope any “view” of the spatial vectorcardiogram, or the scalar derivations from the vectorcardiogram along any axis drawn from the nullpoint in any direction in space. Because this machine enables one to

![Diagram of Panoramic Vectorcardiograph](image)

**Fig. 2.** Block diagram of panoramic vectorcardiograph. The panoramic unit and its cathode ray oscilloscopes are shown in the photograph on the right.

“view” the spatial vectorcardiogram from any angle, we have called it the “panoramic” vectorcardiograph.

**Technic**

Figure 2 shows a block diagram of the panoramic vectorcardiograph, with a photograph of the panoramic unit and its oscilloscopes. The vectorcardiograph (VCG) lead system used in this study is an orthogonal, bipolar system with a common electrode on the back of the right shoulder. The horizontal and anterior-posterior leads lie in the transverse plane passing through the junction of the second rib and the sternum. The electrodes of the horizontal lead are placed at this level, just medial to the posterior

As shown, the three vectorcardiograph leads (vertical, horizontal, and anterior-posterior) from the patient are connected to separate amplifiers. The amplifiers were designed and built in our laboratory, and their response has been shown to be linear over a frequency range of 0.5 to 150 cycles per second. Their response to a continuous 1.0 mv. direct current signal shows less than 3 per cent decrement 0.2 second after the introduction of the signal, and falls to 33 per cent of the original response in 2.7 seconds. These amplifiers together with the direct-coupled amplifiers of the Dumont 394-H cathode ray oscilloscope give a maximum sensitivity of 10 inches per millivolt on the face of the oscilloscope.

The outputs of these amplifiers (horizontal =
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Fig. 3. Block diagram of panoramic unit

Fig. 4. Schematic diagram of the panoramic unit components shown in figure 3
The single-ended outputs of the panoramic unit ($x^*$ and $y^*$) are connected to the plates of a Dumont 304-H oscilloscope through its direct coupled amplifiers, and performs the mathematic transformations:

\[ E_x^* = E_x \cos \phi - E_z \sin \phi \]
\[ E_y^* = E_y \cos \theta + \sin \theta(E_x \sin \phi - E_z \cos \phi) \]

The single-ended outputs of the panoramic unit ($x^*$ and $y^*$) are connected to the plates of a Dumont 304-H oscilloscope through its direct coupled amplifiers.

Vectocardiograms are photographed on 70 mm. photographic paper (Eastman Kodak Linagraph No. 1127), using a "Varitron" camera, Model E,* (not shown in fig. 2) with a Carl Zeiss Tesser f/3.5 lens. Time intervals in the vectocardiograph loops are indicated by modulating the beam intensity so that the trace is blanked every 0.004 second for a period of 0.002 second. The timing signal is not a square wave, but is peaked by a capacitor, so that the dashes which make up the loops are wedge-shaped, and point in the direction of rotation.

Three plane projections of the vectocardiogram are recorded consecutively: frontal, sagittal and transverse. The sagittal view which we use routinely is the view of the spatial vectorcardiogram from the patient's right side. The transverse view is recorded so that the patient's right side lies to the reader's left, and the patient's chest lies toward the bottom of the page.

The $y^*$ output of the panoramic unit is also displayed on a second cathode ray oscilloscope, against a linear time sweep. This scope is used only as a monitor, and the $y^*$ output is recorded on one channel of a Hathaway S-14 C oscillograph.† The outputs of the amplifiers are recorded on other channels of this oscillograph. The galvanometers used are Hathaway Type OC-2, and have an undamped natural frequency of 500 cycles per second. A paper speed of 50 mm. per second is used, and an independent timer registers time lines at intervals of 0.01 second, with heavier lines at 0.05 second and 0.10 second intervals.

To describe three-dimensional data some arbitrary conventions must be adopted, and the spatial coordinate system we have used is shown in figure 5. The zero axis in this system is at the line of intersection of the frontal and transverse planes, on the patient's left side. Position above or below the horizontal plane is termed "elevation" (θ), and is described by the angle between the transverse plane and a line connecting the nullpoint with the point being designated, in a plane perpendicular to the transverse plane. Angles above the horizontal are designated as negative, and those below as positive. Position dorsal or ventral to the frontal plane is termed "azimuth" (ϕ), and is described in terms of projection on the transverse plane. Axes lying anteriorly, that is, ventrally, are designated as positive, and those posteriorly as negative. An observer, for example, whose position was at elevation = 0 degrees, azimuth = +90 degrees would see the frontal plane vectocardiogram.

Any view of the spatial vectorcardiogram can be displayed by adjustment of two controls on the panoramic unit, which are calibrated in terms of the elevation and azimuth of the observer. This is illustrated in figure 6. The first vectocardiogram in the top line in this figure is the standard frontal view of the spatial vectorcardiogram. If we remain at the same elevation, and change the azimuth control through successive intervals such as the 30 degree intervals illustrated, the corresponding views of the vectocardiogram appear on the oscilloscope, so that we move around toward the patient's right side until we see the sagittal view. In the lower line of this same figure, we start again with the frontal view, but this time maintain a constant azimuth and move to successively higher elevations until we look down on the spatial vectorcardiogram from above. In this way, by adjusting azimuth and elevation, we can view the spatial vectorcardiogram from any angle, making its characteristics from all aspects accessible without the construction of wire models or the use of stereoscopy.

In addition, the projection of the spatial vectocardiogram along any single axis can be shown as a scalar electrocardiogram by using only the $y^*$ output of the panoramic unit. As can be seen in figure 2, the vertical component of whatever loop appears on the first oscilloscope will appear as a scalar record on the second, and can at the same time be recorded permanently on one channel of the Hathaway oscil-
lograph. For example, when the frontal plane vectorcardiogram is being displayed on the first scope, the vertical vectorcardiograph lead will appear as a scalar electrocardiogram on the second. (The polarity of the electrocardiograph lead will be inverted in this case, since the frontal vectorcardiogram is recorded with positivity downward, or footward, on the scope; by rotating the elevation control 180 degrees the polarity can be made to conform with the electrocardiographic convention of recording positivity by upward deflections.) Similarly, when the transverse view of the vectorcardiogram is shown on the first scope, the anterior-posterior component of the vectorcardiogram will appear on the second scope. It will be apparent that there is a difference of 90 degrees between the derived scalar lead and the position of the observer viewing the loop, so that it is convenient to have separate scales on the azimuth and elevation controls for these purposes.

In using the panoramic vectorcardiograph to predict from the vectorcardiogram the potential variations to be expected at various points on the body surface, the assumption is made that the electrical field of the heart in the body resembles that of a relatively small dipole source in a homogeneous conducting medium. Clearly, this is at best an approximation, but the point in question is whether it is a sufficiently close approximation to explain the form of the complexes recorded from the precordium and elsewhere, and if not, what discrepancies appear? This can be investigated by comparing complexes recorded by unipolar leads from the body surface, with scalar records, corresponding to the same area, derived by the panoramic unit from the spatial vectorcardiogram. Comparisons of this kind can be only approximate since the location of the null-point in the body is not known with any exactness and we cannot therefore define a given point on the body accurately in terms of our coordinate system. We have tried to avoid this difficulty by taking electrocardiograms from a large number of points on the chest and back, and comparing them with a group of vectorcardiographic derivations corresponding to approximately the same area, rather than attempting a point-by-point comparison. A large number of axes through the vectorcardiograph were explored, using the cathode ray oscilloscope as a monitor; the coordinates at which complexes similar to the actual electrocardiograms occurred were noted, and the complexes recorded. The over-all amplitude of the actual and predicted complexes are not comparable, since the amplitude of all the predicted complexes were arbitrarily adjusted to approximately the same size.

**RESULTS**

Fifty-two patients with heart disease, including cases of myocardial infarction, bundle branch block, and ventricular “strain,” have been studied, as well as six subjects with no evidence of heart disease. The results obtained can best be shown by describing three illustrative cases. In these three cases, as in all cases studied to date, the actual body surface leads and the appropriate scalar derivation from the vectorcardiogram resemble each other very
closely, provided the approximate position of the electrical nullpoint is taken into account.

Case 1. This patient was a white male, 21 years of age, with no evidence of cardiac or other disease. Figure 8 shows some of the electrocardiograms recorded from this subject, and scalar derivations from his vectorcardiogram corresponding to approximately the same area. The upper three lines of records in figure 8 are unipolar (V) leads taken at the three different transverse levels, A, B, and C, indicated in figure 7. The vertical alignment of these leads corresponds to the standard precordial positions and their counterparts on the right chest. Several features of this series of leads are of interest. First, at all three levels the R wave becomes larger and the S wave smaller as we go from the right side of the chest to the left, just as in the normal routine precordial leads. Second, along each vertical line, the R wave becomes larger and the S wave smaller as we move from the upper part of the chest downward. In other words the transitional complexes, in which R and S are roughly equal, are displaced further to the patient's right as we go downward from one level to the next. Third, at level A lead V₆R is a mirror image of lead V₆, and V₆ has the same form as standard lead I. This is not true at level B or C, and suggests that the electrical nullpoint lies near the transverse plane indicated by level A.

All of these characteristics are also found in the scalar vectorcardiographic derivations. The electrocardiograms from level A correspond quite closely to the derivations from the transverse vectorcardiogram (elevation = 0 degrees), as would be expected if the zero point were at this level. In comparing the vectorcardiographic derivations with leads at other levels it is important to realize that the leads taken at any one transverse level are not all at the same angle of elevation with respect to the nullpoint in our spatial coordinate system. This is due to the eccentricity of the nullpoint in the body, so that points along a given horizontal level on the body surface are not equidistant from it. If the nullpoint lies on the left side of the body, which seems probable, then leads on the left side of the chest will be at a greater angle below it than leads on the right side. At the horizontal level passing through the nullpoint this does not apply.

For this reason one would not expect all the vectorcardiographic derivations corresponding to electrocardiograph leads at levels B or C to be found at the same elevation settings, but would expect the greatest angles of elevation for leads on the left chest. This is borne out by the derivations shown in figure 8. To find the scalar vectorcardiograph derivation corresponding to V₆ at level C, for example, it is necessary to move down to elevation = +65 degrees, while the derivation corresponding to V₆R at this level appears at elevation = +50 degrees, and that corresponding to V₆ is at elevation = +30 degrees. Leads V₈, V₈R, and V₈L, taken at the angles of the scapulae and in the midline of the back, also have their counterpart in vectorcardiograph derivations, as shown at bottom right in figure 8.

In this case the P and T waves in the scalar vectorcardiograph derivations resemble those in the actual leads fairly closely. In many cases this is not true, as Jouve⁴ and Duchosal⁵ have pointed out, and it seems probable that the electrical nullpoint assumes a different position for each of the three electrical events represented by the P, QRS, and T deflections.

![Fig. 7. Case 1. Chest x-ray film showing the three levels at which the unipolar electrocardiograms in the first three lines of figure 8 were taken.](image-url)
Fig. 8. Case 1. The records in the first three lines are unipolar (V) electrocardiograms taken at the levels indicated in figure 7. The next three lines show comparable scalar derivations from the spatial vectorcardiogram. The form of the complexes is very similar in the two sets of records. The over-all amplitude of the complexes is not comparable, since the scalar vectorcardiograph derivations were calculated as if all were equidistant from a central dipole. Standard electrocardiograph leads I, II, and III are shown lower left. The paper speed and standardization indicated apply also to the chest leads. In the lower right three unipolar electrocardiograms from the back are shown, again with comparable scalar vectorcardiograph derivations. V₆ and V₈R were taken at the angles of the left and right scapulas, respectively, at level "B" (fig. 7). V₈ML was taken in the posterior midline at the same level.
of the second anterior intercostal space it has the
same form as lead I, suggesting that the electrical
nullpoint lies at this relatively high level in the
chest, just as in case 1. It seems probable, therefore,
that these precordial leads were well below the level
of the nullpoint, and should not be compared with
the transverse plane vectorcardiogram. When we
use the panoramic unit to record scalar vectorcardi-
ograph derivations for angles below the nullpoint, we
find the same QRS transition as in the precordial
leads (fig. 9).

Case 3. This patient was a 40 year old white male
who had shown clinical evidence of acute myocardial
infarction six weeks before the records shown in
figure 10 were made. According to the “semidirect”
theory, the deep Q waves and inverted T waves in
leads V₁ to V₅ would be regarded as local effects
attributable to the proximity of the exploring elec-
trode to the injured myocardium. The same deflec-
tions, however, are reproduced in scalar derivations
from the spatial vectorcardiogram, although the
vectorcardiogram was recorded by leads nowhere
near the precordium.

Discussion

1. Precordial Leads and the Transverse Projection
   of the Spatial Vectorcardiogram

Discrepancies between the precordial electro-
cardiogram and the transverse vectorcardio-
gram have been reported by several investiga-
tors,¹ ² ³ and have been interpreted in different
ways. Duchosal³ has offered the explanation
that there is a continuous displacement of the
nullpoint during the QRS complex. Although
it seems probable on theoretic grounds that
this does occur to some extent, the fact that
the precordial leads do not usually lie in the
same transverse plane as the nullpoint appears
in our cases to be a much more important factor
in producing these discrepancies. When this
factor is taken into account, it is not necessary
to assume a changing locus for the nullpoint
during the QRS.

In many of our cases, as in the three illus-
trated, the QRS nullpoint appeared to lie
much higher in the chest than the anatomic
center of the ventricles, and the standard
precordial positions were therefore below it.
This is in accord with the observation fre-
quently made in the routine reading of electro-
cardiograms, that lead V₅ does not have the
same form as lead I, but more closely resembles
lead II, or a lead along an axis between leads
I and II. Similar findings have been reported
by Jouve and his co-workers,⁴ who state that
the zero point in normal subjects is situated to
the left of the midline, in a horizontal plane
between the third and fifth rib, and that in
cases of right ventricular hypertrophy it is
higher in the chest.

From our preliminary observations in this
regard it seems that there may be a correlation
between the location of the nullpoint and the
mean QRS axis. In the three cases illustrated,
the mean QRS axis lies below the horizontal,
and the nullpoint is relatively high in the chest.
In left bundle branch block and left ventricular
hypertrophy, where the mean QRS axis lies
above the horizontal, the nullpoint in the few
cases we have studied with this point in mind
has been lower, at about the level of fifth an-
terior intercostal space. Further investigation
of the position of the nullpoint in various
cardiac abnormalities is indicated.

2. The “Semidirect” Hypothesis

The Wilson central terminal and unipolar
V leads were introduced because it was thought
desirable to know the “absolute” variations
in potential (measured with reference to an
“indifferent” point) at various points on the
body.¹⁰ Bipolar leads such as standard leads
I, II, and III were considered to be “mixtures”
of electrical information because they were
measurements of the difference in potential
between two points, both of which showed wide
changes of potential during the cardiac cycle.
Aside from the question of whether the poten-
tial variations of the central terminal are in
fact negligible for practical purposes, the elec-
trical information recorded by unipolar leads
would be more useful than that recorded by
bipolar leads only if the cardiac electrical field
were grossly irregular, with preferential con-
duction pathways from certain parts of the
heart to particular parts of the body surface.
If, however, the field were approximately sym-
metric, like that of a simple dipole, then there
would be no essential difference between uni-
polar and bipolar leads, provided the bipolar
electrodes were equidistant from the source.
The wave form recorded by either type of lead
would depend on the axis of the lead in the
Fig. 9. Case 2. A 30 year old female with clinical evidence of rheumatic mitral stenosis. (A) Spatial vectorcardiogram. The details of the P and T loops are shown at higher amplification below each view. The sagittal view is shown as if viewed from the patient’s right side. The transverse view is oriented so that the patient’s right side lies to the reader’s left, and the chest wall toward the bottom of the page. Arrows indicate direction of rotation of the QRS loop. The cathode ray beam is interrupted at intervals to provide a time scale, so that 4 milliseconds elapse from the beginning of one dash to the beginning of the next. (B) Comparison of unipolar precordial leads with scalar derivations from the vectorcardiogram. All precordial leads were taken at the level of the fifth anterior intercostal
electrical field, the axis of unipolar leads being
the line from the exploring electrode to the
electrical nullpoint.

In the cases illustrated, and in our other
cases, it appears that the complexes in unipolar
leads from the precordium or any other
point on the body can be interpreted in terms
of a relatively symmetric electrical field. The
relative proximity of the exploring electrode
to one part of the myocardium seems to be
comparatively unimportant in determining
the general form of the complexes. The fact
that the form of precordial and other unipolar
leads can be predicted from a spatial vectorcar
diogram which is recorded by leads at a
distance from the heart, seems to us incompa
patible with the concept, found in many modern
textbooks of electrocardiography, that the
complexes in unipolar precordial leads repre
sent the electrical activity of the nearest
portion of the heart.

This concept has arisen from an interpreta
tion, which we believe to be erroneous, of the
experiments published by Wilson and his co
workers. These investigators showed in dogs
that the potential variations recorded by uni
polar (V) leads at any point on the precordium
were approximately the same as those re
corded by direct unipolar leads from the under
lying epicardium. From this they concluded
that "... the potential variations of a pre
cordial electrode are determined to a very
large extent by the potential variations of the
elements of ventricular surface nearest it." Un
This is somewhat misleading, for it implies
that the electrical events in the nearest ele
ments of the myocardium are the principal
factor in determining the complexes recorded
by unipolar epicardial or precordial leads. This
was not the authors' intention, for they point
out that even in direct epicardial unipolar
leads the truly local effects are represented
only by the "intrinsic deflection," and add
"... although the excitation of the muscle
in contact with the exploring electrode pro
duces a much larger and much more sudden
fluctuation in the potential of this electrode
than the excitation of any equal mass of muscle
at a greater distance from it, every unit of
ventricular muscle, without exception, produces
action currents which contribute to the form
of these complexes." Unquestionably, the
contribution of each part of the myocardium
must be inversely proportional to its distance
from the exploring electrode; the problem is to
identify, in the complexes recorded from the
body surface, the local contribution. Our
data indicate that the effects contributed
locally must be very small, since the general
form of the complexes is the same as if they
were distant projections of a single dipole.

It might be supposed that the slurring and
notching frequently seen in precordial leads

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**Fig. 10.** Case 3. Unipolar precordial electrocardiogram and scalar projections of the spatial vectorcardiogram from a patient who had clinical evidence of acute myocardial infarction six weeks prior to this record. The characteristic Q and T waves appear in both sets of records, although the vectorcardiogram was recorded from leads distant from the precordium.
recorded by instruments with good high-frequency response might be local effects, and would be absent from the vectorcardiogram. This has not proved to be true in our cases, for in all instances the same slurring and notching appeared in scalar vectorcardiograph derivations. This is consistent with the observations of Kossmann and his co-workers, who found that notches in the complexes recorded by intracardiac leads corresponded to simultaneous notches or peaks in all precordial and extremity leads. It is of interest that in our cases the timing of the notches within the QRS complex was occasionally slightly different in the precordial lead and in the vectorcardiogram, and discrepancies of this kind need to be studied more closely.

3. Clinical Interpretation of Unipolar Leads

The clinical interpretation of unipolar precordial leads rests on empiric foundations which have been gradually built up from clinical and postmortem correlations. The theory that they are semidirect, or local, leads has been fitted into this empiric background without serious incompatibilities, but the validity of most current criteria for interpretation rests on empiric observations and does not depend on the validity of the "semidirect" hypothesis. For this reason the demonstration that precordial leads actually represent summations of electrical activity in all parts of the heart, rather than predominantly local effects, would have little effect on their clinical interpretation.

In case 3, for example, the pattern in the precordial leads is that which has been shown empirically to occur when there is infarction of the anterior wall of the ventricles. We have learned to recognize the changes in the cardiac electrical field which infarcts in this location produce by the presence of characteristic Q waves and T waves in precordial leads, but it can be seen from the spatial vectorcardiogram and the scalar derivations from it that these electrical changes are not restricted to the precordium. The Q waves, therefore, are simply one aspect of the changes in the electrical field throughout the body, and cannot be regarded as a "view" of the electrically negative ventricular cavity through a "window" of necrotic myocardium.

The interpretation of the unipolar extremity leads, on the other hand, and their supposed advantages over bipolar leads, have been based largely on the semidirect hypothesis. Their use to determine anatomic rotation of the heart around various axes is a pertinent example. It has been difficult to test the validity of this practice because there is no reliable method for determining anatomic rotation of the heart in vivo. However, strict adherence to the theory leads in some cases to most unusual conclusions, making it necessary, for example, to assume that the left ventricle lies to the right of the right ventricle. Our results suggest that the unipolar extremity leads are predominantly influenced, not by the particular chamber they "face," but by the axis of the lead in the electrical field of the heart. In this respect, therefore, unipolar extremity leads offer no advantage over bipolar extremity leads.

Summary

1. A "panoramic vectorcardiograph" is described, which will present any desired view of the spatial vectorcardiogram on a cathode-ray oscilloscope. The viewpoint of the observer may be changed at will by adjusting two controls calibrated in terms of his azimuth and elevation with respect to the nullpoint of the vectorcardiogram. This instrument will also calculate and make scalar electrocardiograms representing projections of the spatial vectorcardiogram on any single axis.

2. This device eliminates some of the problems previously encountered in deriving scalar electrocardiograms from the spatial vector-
cardiogram, since the necessary calculations are made automatically, and for any spatial axis.

3. In 58 subjects unipolar electrocardiograms recorded from the precordium and other points on the body surface showed a close resemblance to appropriate scalar derivations from the spatial vectorcardiogram. This was true even in cases of myocardial infarction, where the precordial leads showed changes previously thought to be “local effects” due to the proximity of the exploring electrode and the injured portion of myocardium.

4. Some of the previously reported discrepancies between precordial leads and the transverse vectorcardiogram can be shown to be due to the fact that the electrical nullpoint lies relatively high in the thorax, so that the precordial lead positions lie in a plane which cannot be compared directly with the transverse vectorcardiogram.

5. These results support the general hypothesis of Duchosal that for all body surface leads the electrical field of the heart approximates that of a single relatively small dipole in a homogeneous conducting medium. The form of the complexes in precordial and other unipolar leads appears to depend more on the axis of the lead in the cardiac electrical field than on preferential conduction from one part of the heart to the exploring electrode.

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Sumario Español

A la extensión que tomas precordiales y otras unipolares son influenciadas por la proximidad del electrodo explorador a una porción o la otra del corazón es tópico de considerable debate. Una aproximación al problema es determinar cuán cerca pueden predecir las tomas precordiales por medio de vectorcardiogramas espaciales registrados con tomas relativamente remotas del corazón. El vectorcardiograma panorámico ya citado provee un método conveniente de demostrar esto, puesto que automáticamente registra derivaciones numéricas del vectorcardiograma para cualquier eje espacial. Los resultados indican que los efectos locales no son el factor predominante en la determinación de la forma de los complejos precordiales.

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