A Study of the Spatial Vectorcardiogram in Subjects with Posterior Myocardial Infarction

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A study of 45 spatial vectorcardiograms of patients with posterior myocardial infarction revealed a characteristic upward displacement of the early portion of the QRS $\triangle Q$-loop. Changes in the later portion of the QRS $\triangle Q$-loop may occur as a result of infarction. The possible utilization of such findings in the diagnosis of infarction is discussed.

INTEREST has long been focused upon the relationship between the probable manner of spread of the excitation wave in the human ventricle and the graphic registration of the resulting electric potentials on the body surface.\textsuperscript{1, 2} The historical development of the concepts of the electrocardiographic changes associated with coronary occlusion and myocardial infarction was reviewed by Wilson and co-workers\textsuperscript{4} in 1933, and the association of $Q_1$ with anterior myocardial infarction and $Q_2$ with posterior infarction, now commonly accepted, was emphasized at that time. Repeated attempts have been made to link the mean instantaneous electric vectors responsible for the early portion of the QRS complex with specific anatomic sites in records from both normal subjects and patients with posterior myocardial infarction.\textsuperscript{1, 5, 6, 7, 8} Attention has been directed to the early portion of the QRS complex, perhaps largely because an empiric clinicoelectrocardiographic correlation is more consistently demonstrated in this portion.\textsuperscript{9, 10} The belief that the abnormal Q may result from a delay in conduction which transfers certain electric activity in the depolarization process from its time of normal occurrence in the QRS complex before infarction to a later time in the QRS after infarction\textsuperscript{4} may have further directed attention away from later phases of the depolarization process for signs of infarction.

This study was undertaken to describe some aspects of the pattern of the spatial vectorcardiogram in 45 patients with posterior myocardial infarction. Since the spatial vectorcardiogram presents the mean spatial instantaneous electric vectors produced by depolarization and repolarization of the heart muscle, it is possible that the spatial vectorcardiogram can assist in better understanding of modifications of the electrical activities which occur with infarction of the ventricular myocardium.

Because the time course of migration of the process of depolarization is such as to activate certain portions of the ventricular musculature early and other portions later, infarction of those areas that are depolarized late would not be expected to produce alterations in the early portion of the trace, but rather in the late phases. For example, it appears that the region of the conus of the right ventricle and the posterobasal and subepicardial regions of the left ventricle usually are activated last. Therefore, the recorded wave of depolarization in this instance would not be expected to be altered in its early portions but rather in the more terminal portions. The time courses of the magnitude and spatial direction of the mean instantaneous vectors are presented in such detail in the spatial vectorcardiogram that it is possible that this type of recording may
reveal alterations as a result of infarction involving regions activated late or intermediate in time. These aspects of the data were particularly studied. In addition, other aspects of configuration of the spatial vectorcardiogram were observed, in an attempt to describe certain of its characteristics in posterior myocardial infarction.

**Materials and Methods**

Forty-five patients in whom the diagnosis of myocardial infarction of the posterior or diaphragmatic surface was considered likely have been studied. These included 37 men and 8 women, ranging in age from 44 to 85 years. Thirty-seven included in this study had clinical histories suggestive of myocardial infarction, and 33 patients had electrocardiograms showing evidence of acute infarction a few weeks to several years prior to this study. The remaining 11 patients had electrocardiograms showing Q waves and abnormal T waves in leads II and III at the time of this study which, in association with suggestive clinical data, were considered to have sufficient evidence of posterior infarction to be included in this series. Three patients died, and the presence of posterior infarction was confirmed at autopsy.

The spatial vectorcardiograms were recorded with the equilateral tetrahedral system of electrode placement by means of methods previously reported. Projections of the spatial vectorcardiogram on the frontal, right, left, and superior planes of the reference frame as well as projections on the left surface midplanes perpendicular to these were recorded. The respective perpendicular plane projections were recorded in simultaneous pairs. Stereoscopic views of the projections on each of the plane surfaces of the tetrahedron were also obtained. Electrocardiograms were obtained immediately after the vectorcardiograms were recorded. These included standard leads, bipolar leads formed by the electrode on the back with those on the limbs, unipolar leads from the points defining the apices of the tetrahedron, and precordial leads V1 through V5. Proper pairs of standard and unipolar limb and back leads were recorded simultaneously so that any portion of any lead could be oriented temporally with respect to selected portions of the other leads. Recordings of both electrocardiograms and vectorcardiograms were obtained with the patients in the supine position, with the head elevated approximately 20 degrees from the horizontal plane.

Three-dimensional wire models of the spatial vectorcardiograms were constructed to conform to the contour of the plane projections of the vectorcardiograms. These models and the recorded plane projections and stereoscopic views were studied with respect to the general and detailed configurations and to the spatial orientation of the QRS sE and sE-loops. Special attention was given to differences in orientation and configuration between the QRS sE-loop of normal subjects and the QRS sE-loop of patients with left ventricular enlargement or other cardiac states. Measurements of the length and direction of the maximal instantaneous QRS and T vectors in the frontal and left sagittal plane projections are presented to assist in defining the general range of spatial orientation and size of the loops.

**Results**

**QRS sE-loops**

Forty-one of the records were divided into two groups, A and B, on the basis of similarity in form of the QRS sE-loops. Four records constituted a miscellaneous group in which there was no consistent configuration of the QRS sE-loops.

*Group A*: Twenty-six records were characterized by upward displacement of the early part or all of the efferent limb and by an afferent limb which tended to resemble that of normal records in general contour and spatial orientation. A record that is representative of this group is shown in figure 1.

![Fig. 1. Frontal- and left sagittal-plane projections of examples of QRS sE-loops resembling the two normal types of two patients with posterior myocardial infarction, showing displacement of the early portion of the efferent limb. The QRS sE-loop shown in a resembles the QRS sE-loop of normal type 1 and that in b resembles the normal type 2.](http://circ.ahajournals.org/)

In the illustrations to follow, *Right*, *Inferior* and *Posterior* refer to the subject.
In the frontal-plane projection, 21 of these loops were inscribed in a clockwise direction, whereas five formed figures-of-eight in which the proximal portions were also inscribed clockwise. In the left sagittal-plane projection, six were inscribed in a clockwise and 12 in a counterclockwise direction, whereas eight formed figures-of-eight.

The magnitude and direction of the maximal QRS vectors in the frontal and the left sagittal planes are shown in figure 2. In two of the records the upward displacement of the early portions of the loop was so pronounced that the maximal vectors were located in the first and second sextants of the triaxial reference system in the frontal plane, even though later portions of these loops resembled those of normal subjects. Thus, in figure 2, two vectors are presented to represent each of these records: the maximal vector, in the early portion of the loop, and the smaller, which corresponded more closely temporally with the other maximal vectors.

In table 1 the maximal, minimal and average values of the maximal mean instantaneous vector in this group of records are compared with the values obtained from 75 normal records. It may be seen that the maximal mean instantaneous vectors of the two groups were similarly oriented. In general, the magnitude of the mean instantaneous vectors of the QRS sE-loops in this group was less than that of the normal records. With the exception of the upward displacement of the early portion of the efferent limb, the QRS sE-loops of this group tended to resemble the normal loops.

Those records that were similar to the type 1 normal records had elliptoid configurations with varying spatial orientations. In seven records the trace in the midportion of the loop moved rapidly from left to right to give a slightly truncated appearance to the QRS sE-loops (fig. 3). Those records that appeared more like the normal QRS sE-loop previously described as type 2 had more nearly circular spatial contours with a larger enclosed area lying behind the isoelectric point (fig. 1b). The many variations in configuration of the
The magnitude and direction of the maximal mean instantaneous QRS vectors in the frontal and left sagittal plane projections are shown in figure 2 and table 1. The major areas conformed roughly in location with the maximal vectors, and, thus, these QRS sE-loops were located largely in the first and second sextants of the triaxial reference system of the frontal plane and in the second and third sextants in the left sagittal plane projections. All except one were located almost completely posterior to the isoelectric point. The QRS sE-loop in this one record was located in the second sextant in the left sagittal plane but entirely anterior to the isoelectric point.

In addition to the displacement of the initial and terminal limbs, all QRS sE-loops in this group were distinguished by an arc-like deformity in the efferent limb with the concavity downward. This deformity produced the overall effect of a sagging, oblong configuration in

### Table 1.—Maximal QRS sE-vectors of 45 Patients with Posterior Myocardial Infarction

<table>
<thead>
<tr>
<th>Projection in Frontal Plane</th>
<th>Projection in Left Sagittal Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Magnitude (mv)</td>
</tr>
<tr>
<td><strong>Normal (75)</strong></td>
<td></td>
</tr>
<tr>
<td>Maximal</td>
<td>1.73</td>
</tr>
<tr>
<td>Minimal</td>
<td>0.31</td>
</tr>
<tr>
<td>Average</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Group A: Posterior Infarct (26)</strong></td>
<td></td>
</tr>
<tr>
<td>Maximal</td>
<td>1.11</td>
</tr>
<tr>
<td>Minimal</td>
<td>0.28</td>
</tr>
<tr>
<td>Average</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>Group B: Posterior Infarct (15)</strong></td>
<td></td>
</tr>
<tr>
<td>Maximal</td>
<td>3.42</td>
</tr>
<tr>
<td>Minimal</td>
<td>0.34</td>
</tr>
<tr>
<td>Average</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>All Posterior Infarcts†</strong></td>
<td>Average (45)</td>
</tr>
</tbody>
</table>

* Numbers in parenthesis indicate number of subjects.
† Includes 4 miscellaneous tracings not grouped under A or B.

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Fig. 4. Examples of the QRS sE-loops of three patients with myocardial infarction, in which both the late portion of the afferent limb and the early portion of the efferent limb are displaced upward. Note the upward orientation of the T sE-loops in a and c.

the frontal plane projection except in those examples with a figure-of-eight pattern (fig. 4, a and b). Four of the 15 QRS sE-loops in group B had a greater upward displacement of the early portion of the efferent than that of the late portion of the afferent limb. This resulted in clockwise inscription of the loop in the frontal plane (fig. 4c).

Miscellaneous Group: There remained four records with QRS sE-loops whose contours could not be classified in groups A or B. These could be removed from immediate consideration because of the presence of a complicating lateral infarction or extension in one and a complicating anterior infarct in the other three. One of the latter three also demonstrated right bundle branch block.

Fig. 5. Examples of typical T sE-loops in a young normal adult, a patient with left ventricular hypertrophy, and a patient with posterior myocardial infarction. Consult the text for details.

T sE-loops

A distinctive long, narrow, line-like, upwardly directed T sE-loop was noted in 19 of the 37 records in which the T sE-loops were suitable for study (fig. 5). It was usually directed along the -60 degree axis of the triaxial reference system of the frontal plane projection. In 15 of these the T sE-loop in the left sagittal plane projection was directed slightly posteriorly as well as upward and in four, slightly anteriorly. Of the remainder, seven T sE-loops appeared similar to the loops in normal subjects whereas 10 were similar neither to normal nor to the typical upwardly directed loops. Eight of these 10 abnormal T sE-loops appeared similar to the small, round, open T sE-loop described for left ventricular hypertrophy (12). The magnitude and direction of the maximal mean instantaneous spatial vectors of the T sE-loops are shown in figure 6.

Discussion

During the course of analysis of the spatial vectorcardiograms, it became evident that the term "initial" mean instantaneous spatial vector of the QRS sE-loop was difficult to define and often even more difficult to locate. Because of muscular tremor, interfering currents, and other artifacts, it was not possible to determine with certainty in most, if not all,
records the "first" vector of the QRS $sE$-loop. By connotation, the initial mean instantaneous vector is the first one. Since it was not possible to identify with certainty the first one, the "early," definitely identifiable vectors were studied. Although no specific time in the cycle of the QRS $sE$-loop was considered in these studies, the early vectors most probably occurred during the first 0.04 second of ventricular depolarization. It is also well to note that the truly initial vectors may not be concerned with or influenced by the infarcted areas, a problem yet unsolved.

Characteristic changes in the early portions of the QRS complex and QRS $sE$-loop as a result of myocardial infarction are well known from studies in electrocardiography.\textsuperscript{5, 8, 9, 10} It is likely that changes in later portions of these complexes also occur, but these have been neglected. This has been attributed, at least partially, to the rather wide variability of the later portions of the QRS complexes. A similar wide variability in orientation but not in configuration of QRS $sE$-loops in the normal and in certain abnormal states has been noted. For example, it was found that all of a series of QRS $sE$-loops in young normal adults could be classified into two groups on the basis of contour.\textsuperscript{11} It has also been found that QRS $sE$-loops typical of left ventricular hypertrophy have a relatively constant and characteristic contour.\textsuperscript{12} The relatively few variations in the configuration of normal and some abnormal QRS $sE$-loops may facilitate detection of the effects of infarction in later portions of the depolarization process.

In this series, the early portion of the QRS complex and the QRS $sE$-loop were altered as compared with the normal in all instances, since this was one of the criteria for selection of cases. In some QRS $sE$-loops, as far as could be determined, only the early portion had been altered by infarction, whereas other traces presented alterations of later portions of the loop as well, which could be assumed to have been the result of infarction. The frontal plane vectorcardiogram in a patient with posterior myocardial infarction described by Wilson and Johnston probably belonged to this group.\textsuperscript{13} For example, in the instance of the QRS $sE$-loop of figure 3, infarction or death of an area of myocardium which normally would have been activated midway in time during ventricular depolarization most probably resulted in loss of the manifested electric vectors of depolarization and, thereby, in distortion of

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**Fig. 6.** The location in the frontal and left sagittal plane of the projections of the maximal mean instantaneous $T$ $sE$-vectors for 34 patients with posterior myocardial infarction. The mean is indicated by the circled dot in each plane. The magnitude in millivolts is indicated by the scale.
the QRS sE-loop at that moment. Although this theoretic concept supported by indirect evidence seems obvious, correlations with carefully studied postmortem data are necessary to establish the validity of the concept. It is well to note that the electrocardiogram (fig. 3), at least, recorded at standard paper speed 25 mm. per second failed to disclose evidence of distortion of the later phases of the depolarization process. Such changes in the later portions of the QRS sE-loop, most probably due to the location of infarcts, were noted for eight subjects, whereas the conventionally recorded electrocardiogram failed to reveal the distortions.

In general the change in the QRS sE-loop which is to be expected in diaphragmatic surface infarction is the appearance of more and larger vectors directed upward. This change is seen in its simplest form in the records described as group A. Here the major alteration appears to be in the initial portion of the QRS sE-loop. Except for this portion directed upward to the frontal projection, these QRS sE-loops might be considered to resemble those of the normal in orientation and general contour. Theoretically, these vectors might also be directed anteriorly or posteriorly, depending on the location of the infarct on the diaphragmatic surface of the heart, and, in contrast to other studies, considerable variation in the upward direction of these vectors was observed.

The form and orientation of the QRS sE-loops of group B can be explained mainly on the basis that infarction of the diaphragmatic surface of the heart produced varying degrees of upward displacement of both afferent and efferent limbs. Upward displacement of the afferent limb, however, may be due to infarction of the posterior and basal regions of the left ventricle which are depolarized late in the electrical systolic cycle (fig. 4). Left ventricular hypertrophy alone or in association with a posterior basal infarct may have also deviated the terminal portion of the afferent limb superiorly or upward.

It is interesting to note that infarction did not necessarily obscure the vectorcardiographic features of left ventricular hypertrophy. Conversely, the arc-like appearance of the efferent limb of these QRS sE-loops was not encountered in a series of records from patients with typical vectorcardiographic characteristics of left ventricular hypertrophy without clinical and electrocardiographic evidence in infarction.

Well known theoretic considerations in electrocardiography account for the deviation of the mean instantaneous spatial vectors away from the infarcted area (fig. 1). This appeared to be true not only for the early phases of depolarization but for the late ones as well. Apparently, losses of the electric activity of depolarization of a segment of myocardium tended to produce concave distortion in the QRS sE-loop (fig. 4).

The T sE-loop was spatially oriented essentially parallel to and in the same direction as the early mean instantaneous vectors of the QRS sE-loop (figs. 4 and 6). This would be expected from existing electrocardiographic knowledge of the changes and the mechanism for their formation in infarction. Because these records were obtained at widely varying intervals following development of the infarct, this relationship between the T sE-loop and the QRS sE-loop varied from the typical in many instances.

Summary

(1) The spatial vectorcardiograms of 45 patients with posterior myocardial infarction have been studied and described.

(2) The spatial vectorcardiogram in posterior myocardial infarction differed from the normal. The initial portion of the efferent limb of the QRS sE-loop in all instances, except one, showed a characteristic upward displacement; there was an additional upward displacement of the afferent limb in many instances. Many records displayed a long, line-like T sE-loop directed upward and to the left, corresponding to the negative T₃ pattern observed in the conventional electrocardiogram.

(3) The possibility of utilizing data obtained from the later vectors of depolarization has been discussed.

(4) Further study, especially with postmortem correlation, is required to ascertain
the clinical and diagnostic value in posterior myocardial infarction of the additional data available in the spatial vectorcardiogram not detectable in the electrocardiogram with the use of the conventional standard and chest leads.

**SUMMARIO IN INTERLINGUA**

1. Esseva studiate e describile le vectorcardiogrammas spatial de 45 patientes con infarimento myocardial posterior.

2. Le vectorcardiogramma spatial in infarimento myocardial posterior differeva ab le norma. Le portion inicial del membro efferente del spira QRS e mostrava in omne casos, con un exception, un caracteristic displaciamimento in alto. In multe casi il haveva addicionalmente un displaciamimento in alto in le membro afferente. Multe registrationes exhibiva un longe spira T orientate in alto e verso le sinistra, correspondent al negative configuration T3 que se observa in le electrocardiogramma conventional.

3. Es discutite le possibilitate de utilizar datos obtenite ab le vectores ulterior de dispolarisation.

4. Studios additional—specialmente in re correlaciones post morte—es requirite pro determinar le valor clinic e diagnostic representate in casos de infarimento myocardial posterior per le datos additional que es detegibile in le vectorcardiogramma spatial sed que non es detegibile in le electrocardiogramma per medio del derivationes standard e thoracic in uso conventional.

**REFERENCES**

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