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

By G. E. Burch, M.D., Leo Horan, M.D., J. A. Abildskov, M.D. and J. A. Cronvich, M.S.

A study of 45 spatial vectorcardiograms of patients with posterior myocardial infarction revealed a characteristic upward displacement of the early portion of the QRS sE-loop. Changes in the later portion of the QRS sE-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.1.2.3 The historical development of the concepts of the electrocardiographic changes associated with coronary occlusion and myocardial infarction was reviewed by Wilson and co-workers4 in 1933, and the association of Q1 with anterior myocardial infarction and Q2 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.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.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 infarction4 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

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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 V6. 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-loop 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 efferent 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.](#)
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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

![Fig. 2. The location in the frontal and left sagittal planes of the projections of the maximal mean instantaneous QRS sE-vectors for all 45 patients with posterior myocardial infarction. The average is represented by the circled dot in each plane. A and B represent the maximal vectors that occurred in the early portion of two loops of group A; A' and B' represent the lesser vectors that corresponded more closely temporally with the other maximal vectors of that group. (These two sets of vectors from the respective QRS sE-loops were of almost equal magnitude). The scale indicates magnitude in millivolts.](http://circ.ahajournals.org/doi/abs/10.1161/01.CIR.411.3.411?journalCode=circ)
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>Magnitude (mV)</td>
<td>Angle (Degrees)</td>
</tr>
<tr>
<td>Normal (75)*</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>Group A: Posterior Infarct (28)*</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>Group B: Posterior Infarct (18)*</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>
</tbody>
</table>

All Posterior Infarcts†

| Average (45)* | 0.71 | +14 | 0.54 | +31 |

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

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

plane projections represented variations in spatial orientation of basically similar QRS sE-loops.

Group B: Fifteen records were grouped together because of the common characteristics of upward displacement of the portions adjacent to the isopotential point in both the afferent and efferent limbs of the QRS sE-loop. By upward displacement is meant displacement largely into the second sextant of the triaxial reference system of the frontal plane.

The degree of upward displacement was more pronounced in the afferent limb in all 11 of these loops, and, thus, the direction of inscription in the frontal plane projection was counterclockwise in all except the four in which figure-of-eight configurations were found. In the left sagittal plane projection, five QRS sE-loops were inscribed in a counterclockwise and six in a clockwise direction.

Fig. 3. An example of the QRS sE-loop of a patient with posterior myocardial infarction, in which the trace moved rapidly from left to right and also produced a slightly truncated appearance of the QRS sE-loop. Note that the accompanying routine electrocardiogram does not suggest an abnormality in the midportion of the QRS complex.
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 limb 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.

**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. 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. It has also been found that QRS sE-loops typical of left ventricular hypertrophy have a relatively constant and characteristic contour. 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. 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...
the QRS sE-loop at that moment. Although this theoretic concept supported by indirect
evidence seems obvious, correlations with care-
fully studied postmortem data are neces-
sary 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 prob-
able 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.1 7, 14, 15,
16, 17, 18 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 that
portion directed upward to the frontal projec-
tion, these QRS sE-loops might be consid-
ered to resemble those of the normal in orienta-
tion 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,19
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 infarc-
tion 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. Con-
versely, the arc-like appearance of the efferent
limb of these QRS sE-loops was not encoun-
tered in a series of records from patients with
typical vectorcardiographic characteristics of
left ventricular hypertrophy without clinical
and electrocardiographic evidence in infarc-
tion.

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 dis-
tortion in the QRS sE-loop (fig. 4).

The T sE-loop was spatially oriented essen-
tially 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 inter-
vals 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 pos-
terior 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 displace-
ment; there was an additional upward displace-
ment of the afferent limb in many instances.
Many records displayed a long, line-like T
sE-loop directed upward and to the left, corre-
sponding to the negative T3 pattern observed
in the conventional electrocardiogram.

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

(4) Further study, especially with post-
mortem 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 describite le vectorcardiagrammas spatial de 45 patientes con infarcimento myocardial posterior.

2. Le vectorcardiogramma spatial in infarcimento myocardial posterior differeva ab le norma. Le portion initial del membro efferente del spira QRS se mostrava in omne casos, con un exception, un characteristic displaciamiento in alto. In multe casos il habeva additionalmente un displaciamiento in alto in le membro afferente. Multe registraiones exhibiva un longe spira T se, orientate in alto e verso le sinistra, correspondente al negative configuration T3 que se observa in le electrocardiogramma conventional.

3. Es discutite le possibilitate de utilisar datos obtenite ab le vectores ulterior de dis-polarisation.

4. Studios additional—specialmente in re correlaciones post morte—es requirite pro determinar le valor clinic e diagnostic representate in casos de infarcimento 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 thorace in uso conventional.

**REFERENCES**


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