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

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In 20 subjects with anterior myocardial infarction the early portions of the QRS sE-loop were directed away from the area of infarction. Deformities that occurred in later portions of the QRS sE-loop were compatible with loss of electric force produced by depolarization of areas activated late in the phase of depolarization. This observation is of significance because vectorcardiograms, as conventionally recorded and interpreted, fail to detect infarcts located in areas of the heart that are depolarized late and that would not be expected to deform the early portions of the QRS complex sE-loop.

The influence of anterior myocardial infarction upon the spatial vectorcardiogram has interested several investigators,1,2,4 but none of their studies here included extensive use of the equilateral tetrahedral system of electrode placement, and some have not used it at all. The present investigation of anterior myocardial infarction was concerned not only with a description of the spatial vectorcardiogram obtained with the equilateral tetrahedral reference frame but also with the possible influence of infarction in areas of the heart that are depolarized late upon those portions of the QRS sE-loop that are inscribed late. This is of particular interest because the QRS complex, as conventionally recorded electrocardiographically, may reveal infarction in those portions of the myocardium that are depolarized early during excitation. As discussed previously in a spatial vectorcardiographic study of posterior myocardial infarction,6 it is theoretically possible for an infarct to be so localized in an area of the heart that diagnostic alterations in the conventional electrocardiogram are indefinite or unrecognizable.

Methods and Materials

The method for recording the spatial vectorcardiogram (sVCG) is that previously described with the use of the equilateral tetrahedral reference frame.7,8 Electrocardiograms were recorded, as previously described, a few minutes before or after recording of the sVCG with the subject lying in bed in the same position for both studies. Electrocardiograms recorded at other times for routine clinical purposes were also studied and integrated into the investigations of these subjects.

Twenty subjects with anterior myocardial infarction were observed, 18 were ambulatory outpatients of the Charity Hospital. Because a mobile vectorcardiograph was not previously available, only two of the subjects included in this series had recent infarcts at the time the recordings were obtained; the remainder were ambulatory and their infarcted areas were clinically healed. Table 1 summarizes the clinical data on the subjects. Postmortem confirmation was available for only two subjects; the basis for the diagnosis of anterior myocardial infarction in the other 18 subjects consisted of a typical clinical syndrome supported by serial laboratory and electrocardiographic data. Whenever the diagnosis was doubtful, the subject was not included in this series. The clinical diagnosis of ventricular hypertrophy was made only in the presence of a likely etiologic factor and of either fluoroscopic or postmortem evidence of ventricular enlargement.

Four subjects had complete bundle branch block (right or left) and 12 had left ventricular hypertrophy (table 1).

Results

All QRS sE-loops in this series (figs. 1 to 7) were readily recognized as being different from the normal types 1 and 2 described for normal young adults.9

The QRS sE-loop. The mean instantaneous vectors of the early portions of the QRS sE-loop were directed away from the areas of

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This study was aided by a grant from the U. S. Public Health Service (H 143).
infarction (fig. 1), a characteristic previously described.\textsuperscript{10,12} For example, in figure 1 the infarct apparently was located in the anterior and septal region of the heart near the spiral and diaphragmatic locations, and the early vectors were directed toward the subject’s left, superiorly, and posteriorly, that is, essentially away from the infarcted zone.

Many of the QRS sE-loops had sharply defined deformities in contour, some consisting of relatively smooth arcs (fig. 1), whereas some had segments that were straight, tending to produce sharp angularities in the loop (figs. 2, 3). When there were two or three straight segments in a loop, the QRS sE-loop tended to assume a triangular or rectangular configuration (figs. 2 and 3). These alterations in contour occurred in any portion of the loop, late and midportions as well as early portions.

The presence of left ventricular hypertrophy in subjects with anterior myocardial infarction tended to add to the existing configuration of the QRS sE-loop, described previously for left ventricular hypertrophy alone.\textsuperscript{13} Accordingly, the resultant QRS sE-loop was large and oriented in the first and sixth sextants of the triaxial reference system in the frontal plane and posteriorly and in the first and sixth sextants of a triaxial reference system applied to the left sagittal plane (fig. 4). The QRS sE-loop usually had a smooth contour, which was distorted, in part at least, by alterations in the spatial vectors caused by death of muscle in the infarcted zone (fig. 1) and by disturbances in the order of depolarization such as exist with bundle branch block (fig. 3). Left ventricular hypertrophy also tended to increase the duration of the QRS sE-loop.

In subject 9 with infarction of the anterolateral region of the free wall of the left ven-
FIG. 1. Spatial vectorcardiogram and electrocardiogram of subject 5 with an anteroseptal myocardial infarct extending onto the diaphragmatic surface of the heart and with left ventricular hypertrophy. The early portion of the QRS sE-loop consists of vectors in the first sextant of the frontal and left sagittal planes, i.e., directed superiorly, posteriorly and to the left. The spatial vectorcardiogram shows the configuration and orientation characteristic of left ventricular hypertrophy. The efferent limbs of the QRS sE-loop are arched superiorly, probably because of the loss of those electric vectors associated with depolarization as a result of infarction of the diaphragmatic surface of the heart near the apex. The loops in all illustrations, unless otherwise stated, are traced in the direction of the blunt end of the interrupted segments of the trace. The labels indicate the reference directions with respect to the subject.

FIG. 2. Spatial vectorcardiogram and electrocardiogram of subject 11 with a large anterolateral myocardial infarct and left ventricular hypertrophy. Note the triangular shape of the QRS sE-loop in the left sagittal plane projection. The early portion of the QRS sE-loop is directed away from the area of infarction. The triangular shape of the QRS sE-loop may be due to loss of electric activity in those areas of infarction that are usually depolarized later in electric systole.
tricle and the anterior half of the septum near the base, the early portion of the QRS sE-loop was displaced inferiorly, anteriorly, and to the right of the isopotential point (ip) (fig. 5). This subject also had left ventricular hypertrophy, which caused displacement of the later portions of the QRS sE-loop superiorly and posteriorly, and to the left of ip (fig. 5). All of these anatomic changes were confirmed at autopsy one month later, with the additional finding of recent pulmonary embolism.

**The Junction J.** In most instances the junction, J, could not be sharply localized because of interfering currents from skeletal muscle, noises in the amplifiers, and extraneous sources. In some instances, however, and especially when the shifts from ip were large, the point at which the QRS sE-loop ended and the T sE-loop began (corresponding to the junction, J) was readily identified. In the presence of left ventricular hypertrophy, J was displaced to the right, anteriorly, and slightly superior or inferior to ip (fig. 5). This varied somewhat, however, as shown in figures 2 and 6, when it was slightly superior to and to the left of ip. In subject 10 with right bundle branch block (fig. 3), J was oriented anterior to, to the left of, and only slightly superior to ip, whereas the T sE-loop began at J but rapidly rotated in-
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Fig. 5. Spatial vectorcardiogram and electrocardiogram of subject 9 with high lateral myocardial infarction of the left ventricle with left ventricular hypertrophy confirmed at autopsy. The early portion of the QRS sE-loop is directed inferiorly, anteriorly and to the right of the isopotential point (ip), and away from the area of infarction. The direction of inscription in this recording is toward the pointed end of the interrupted segments. The mid and terminal portions of the loop manifest evidences of left and right ventricular hypertrophy, respectively. Although right ventricular hypertrophy was not demonstrated at autopsy, the presence of a recent pulmonary embolism may make the latter observation significant. J is oriented superiorly and anteriorly to and to the left of ip whereas the T sE-loop is spatially oriented anteriorly, to the right, and essentially in the same horizontal plane with ip. J and the T sE-loop are poorly shown because of the halo but were discernible in the original photographic negatives.

Fig. 6. The spatial vectorcardiogram shown in figure 2, recorded at greater gain to show J and the T sE-loop in anterolateral myocardial infarct in detail. J is oriented superiorly, anteriorly and to the left of the isopotential point (ip) or is displaced in the direction of the infarcted zone, whereas the T sE-loop is spatially oriented inferiorly, anteriorly and to the right of ip, as is to be expected in anterolateral infarction and left ventricular hypertrophy, according to existing principles in electrocardiography.

feriorly and posteriorly and to the left of ip (fig. 3).

As were the configuration of the QRS sE-loop and spatial orientation of the T sE-loop, so too was the spatial orientation of J influenced by complicating cardiac disease states, such as ventricular hypertrophy, bundle branch block, pre-existing infarction, diffuse and local myocardial degeneration due to systemic disease, digitalis therapy, and extracardiac disease that influenced the electric field and cardiac position. In the subjects without any complicating cardiac disease except coronary disease (subject 13), the T sE-loop tended to be displaced away from the infarcted area (fig. 7), as would be expected from existing electrocardiographic knowledge. Furthermore, in these subjects, the T sE-loop was often narrow and, in general, had the configuration of a normal T sE-loop, differing primarily in spatial orientation (fig. 7).
**Fig. 7.** Spatial vectorcardiogram and electrocardiogram of subject 13 with diaphragmatic and posterolateral myocardial infarction. The QRS s\(\varepsilon\)-loop manifests the influences of these lesions. The T s\(\varepsilon\)-loop (not shown well because of the halo) is narrow and spatially oriented superiorly, posteriorly, and to the right of the isopotential point (ip), or characteristically away from the infarcted area. The arch of the efferent limb of the QRS s\(\varepsilon\)-loop that is superior to and to the right of ip, i.e., away from the infarcted area, is a characteristic discussed in the text as a possible deformity of the QRS s\(\varepsilon\)-loop that may be a frequent and significant manifestation of infarction.

**Discussion**

The spatial orientation of the early portions of the QRS s\(\varepsilon\)-loop in subjects with anterior myocardial infarction conformed with existing knowledge in electrocardiography.\(^7\)\(^{10-12}\) The early mean instantaneous electric vectors caused by depolarization were directed away from the zone of infarct. Because of the complicating cardiac states and the limited number of records for study, it was not possible to identify in time and space the important mean instantaneous vectors that may be particularly influenced by the area of infarction. Therefore, it was decided, as previously,\(^6\) to refer only to the early portions of the QRS s\(\varepsilon\)-loop. Furthermore, in these subjects the anterior infarcts included infarcts in the septal region, anterior surface, apical area, and lateral surface. In several instances it was likely that the infarct extended onto the anterior part of the diaphragmatic surface of the heart. The area of infarction that influenced the order of depolarization most and earliest in the electric cycle would seem to have the most significant influence upon the orientation of the early portions of the QRS s\(\varepsilon\)-loop. Apparently, the magnitude and temporal relationships of the component areas of depolarization were important in determining the spatial orientation of the mean instantaneous vectors.

The early portion of the QRS s\(\varepsilon\)-loops of eight subjects in this series was directed to the left, superiorly, and posteriorly (fig. 1); these subjects had electrocardiographic evidence of anteroseptal infarction. In 10 subjects it was directed inferiorly and either slightly anteriorly or posteriorly and slightly to the right (fig. 3); these subjects had involvement of the lateral wall of the left ventricle. In two subjects with electrocardiographic evidence of only lateral wall involvement, the early portion of the QRS s\(\varepsilon\)-loop was directed inferiorly, anteriorly, and to the right (fig. 5). When involvement of the diaphragmatic surface of the heart also existed, as it did in four subjects, the early portion of the QRS s\(\varepsilon\)-loop varied considerably because of complicating or multiple infarctions but was generally directed away from the area of infarction.

The configuration and spatial orientation of the remaining portions of the QRS s\(\varepsilon\)-loop
were especially influenced by complicating cardiac states, such as right or left ventricular hypertrophy, or conduction defects, such as bundle branch block, but in all the records studied there remained recognizable evidence of all of these complicating states.\textsuperscript{5, 7, 12, 13} The duration of the QRS \textit{sE}-loop was increased by left ventricular hypertrophy, probably because of the increased thickness of muscle that the process of depolarization had to traverse. These observations agree with those of investigators who employed other reference frames.\textsuperscript{1-5}

The later portions of the QRS \textit{sE}-loop appeared to be deformed by the effect of the areas of infarction upon those processes of depolarization that invade the infarcted myocardial areas later in the electric cycle. These deformities in contour were compatible with a reduction or loss of electric activity in the infarcted areas, resulting in mean instantaneous vectors that were directed away from the infarcted areas or, if directed toward those areas, were reduced in magnitude (figs. 1, 2, 5 and 7). The resultant effect on the QRS \textit{sE}-loop was to appear to remove a section from that portion normally associated with electric activity in the infarcted area within the heart. In figures 1 and 2, for example, an infarct on the diaphragmatic surface of the heart produced arching of the efferent limb of the QRS \textit{sE}-loop. Anatomic and spatial vectorcardiographic correlations in experimental animals and man will be necessary to evaluate this concept adequately, but electrocardiographic and other clinical data, as well as theoretic electrocardiography, seem to support the concept. So far, distortions and alterations in the electrocardiogram correlate well in time and in magnitude with the distortions of the late portion of the QRS \textit{sE}-loop and the areas of infarction. If the electrocardiograms had been recorded at a more rapid film speed, and if the frequency characteristics of the electrocardiograph were satisfactory, the deformities in the QRS complex could also be identified electrocardiographically. The extent remains unknown to which the QRS \textit{sE}-loop and recordings with the specially constructed electrocardiograph may reveal alterations caused by infarction and other localized lesions that modify the order of depolarization late in electric systole. This is a fruitful field for study. Surely, infarcted zones of the myocardium localized to areas that are depolarized late cannot be expected to modify the early portions of the QRS \textit{sE}-loop. Any disturbance other than infarction that interferes with the invasion or the order of depolarization of an area of the myocardium that is depolarized late in the electric cycle may produce deformities late in the QRS \textit{sE}-loop. When all data, including clinical data, are properly considered, fairly reliable differentiations may be made. Further investigation is necessary for proper evaluation of these concepts and problems.

As with the QRS \textit{sE}-loop, the spatial orientations or configurations of J and the T \textit{sE}-loop conformed to the well known principles of electrocardiography.\textsuperscript{7, 10-12} J tended to be displaced toward the area of infarction and the T \textit{sE}-loop away from it (fig. 6). The T \textit{sE}-loop tended to be narrow or hairpin in shape and to be oriented away from the infarcted area when infarction was the major lesion. In the presence of severe left ventricular hypertrophy, it tended to be C or horseshoe shaped, a configuration previously described for many spatial vectorcardiograms in left ventricular hypertrophy.

\textbf{Summary}

The electrocardiograms and spatial vectorcardiograms of 20 subjects with anterior myocardial infarction were studied. The early portions of the QRS \textit{sE}-loop were directed away from the area of infarction. Deformities observed in later portions of the QRS \textit{sE}-loop were compatible with loss of manifested electric forces produced by depolarization of areas activated late in the phase of depolarization. This observation is of particular significance because electrocardiograms, as conventionally recorded and interpreted, fail to detect infarcts located in areas of the heart that are depolarized late and that would not be expected to deform the early portions of the QRS complex and QRS \textit{sE}-loop. Although associated changes in time and magnitude
existed late in the QRS complex of the electrocardiogram, their significance would be overlooked in the conventional recording and interpretation.

The junction, J, was spatially oriented toward the area of infarction, whereas the T sşE-loop was oriented away from the zone of infarction.

Complicating cardiac states, such as right and left ventricular hypertrophy or both, right or left complete bundle branch block and digitalis, tended to alter the spatial vectocardiogram accordingly. These complicating factors must be considered when the spatial vectocardiogram is being evaluated. The modifying influence of all of them was recognizable but did not completely camouflage the influences of the infarcts.

**SUMMARIO IN INTERLINGUA**

Esseva studiate le vectocardiagrammas e le vectocardiagrammas spatial de 2o patientes con infarimento myocardial anterior. Le prime portiones del ansa sşE de QRS habeva un direction abiente ab le area del infarimento. Deformitates observate in subsequeente portiones del ansa sşE de QRS esseva compatibile con perdita de manifeste fortias electric producite per le dispersolisation de areas a activation plus tarde in le phase de dispersolisation. Iste observation es de signification special proque vectocardiagrammas de registration conventional, interpretate conventionalmente, non detege infarimentos locate in areas de dispersolisation tardive que non pote causar un deformation del prime portiones del complexo QRS e del ansa sşE de QRS. Ben que associate alterationes temporal e magnitudinal existeva plus tarde in le complexo de QRS del electrocardiagramma, lor signification non esserea notate per methodos conventional de registration e interpretation.

Le junction J esseva spatialmente orientate verso le area del infarimento durante que le ansa sşE de T habeva un direction abiente ab le zona del infarimento.

Complicationes del stato cardiac—per exemplo hypertrophia dexterore—e/o sinistro-ventricular, bloco complete del branca dextere o sinistre, e digitalis—tendeva a alterar le vectocardiogramma correspondentemente. Tal factores complicatori debe esser prendite in consideration quando on evaluta le vectocardiogramma spatial. Lor influentia modificatori esseva recognoscibile sed non amontava a mascar completamente le influentia del infarcimentos.

**REFERENCES**

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Circulation. 1956;13:360-367
doi: 10.1161/01.CIR.13.3.360
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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