AN APPRECIATION OF SPATIAL VECTORCARDIOGRAPHY

II. CLINICAL APPLICATIONS

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Spatial vectorcardiograms (SVGs) were recorded on some 50 patients, all of whom had been fully investigated by routine methods, including cardiac catheterization where necessary. No particular selection of patients was made, other than that they all presented with cardiac abnormalities of greater or lesser severity. While the results in each case are of interest, only those cases needed to indicate some of the advantages of spatial vectorcardiography in clinical practice will be discussed here.

INTERPRETATION OF NORMAL VECTORCARDIOGRAMS

*The figures (SVGs) which follow can be rendered intelligible only by comparison with the normal as drawn in Fig. 3, Part I,*** which should be consulted throughout. F, H, and S in Figs. 1 - 7 indicate frontal, horizontal and sagittal views, respectively. The large white blob in each figure corresponds to the lead axis intersect, and represents iso-electric potential. This point is unduly enlarged by auricular activity, always too small to be separately visible. The T loop begins and ends at the same spot, and where it is of sufficient amplitude it can be seen as a distinct projection. In every case the prominent loop is that resulting from ventricular depolarization (QRS loop).

Invariable normal findings are: (1) Initial movement of the QRS loop to the right and anteriorly from the iso-electric point; (2) an anti-clockwise rotation of the loop, as seen in the horizontal and left sagittal planes; (3) a fairly uniform speed of rotation of the cardiac vector throughout ventricular depolarization — this is seen as even spacing of the dots composing the loops [occasionally the dots (time markers) may be seen a little more closely approximated to each other at the beginning and the end of the QRS loop than in the middle (Fig. 1)]; (4) the mean QRS vector (i.e. the single vector force representing the mean of the innumerable mean instantaneous QRS vectors) usually falls within the angle between the left arm and the feet, in the frontal plane; (5) the loops are smoothly contoured.

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** See Fig. 3 at the top of this page.

These findings may be rationalized by recalling that the bundle of His lies in the posterior part of the interventricular septum, that the septum is the first part of the ventricular muscle to be depolarized, and that septal depolarization normally occurs from left to right. This explains the direction of the initial mean instantaneous QRS vectors to the right and anteriorly. The unimpeded flow of the accession wave through normal conduction pathways and ventricular muscle yields gradually varying instantaneous vectors — hence the smooth contours to the loops and the approximately even time course of inscription.

CASE REPORTS

Case 1, S.T.

This healthy young man was subjected to 'routine' electrocardiography; this revealed a slurred S wave in V_1, and he was accordingly referred for spatial vectorcardiography (Fig. 1). His SVG shows all the normal features enumerated above. In addition, however, there is an abrupt projection, in both sagittal and horizontal planes, on the posterior near-terminal part of the otherwise smoothly contoured QRS loop. This corresponds electrically to the slurred S wave seen in V_1, which must then represent a local fault, of unknown nature, in ventricular depolarization.

Case 2, Miss E.

Fig. 2 shows the frontal and horizontal plane projections of the spatial vectorcardiogram of Miss E., a 15-year-old girl with mild pulmonary stenosis. Cardiac catheterization showed a pulmonary artery pressure of 15 mm. Hg, and a right ventricular pressure of 34 mm. Hg. The only significant abnormality in the ECG was an rsR pattern in V_1.

The SVG, however, is strikingly abnormal. In the frontal plane the QRS loop is seen to be flattened from top to bottom, and to project considerably to the right of the iso-electric point. The horizontal plane projection confirms this. The time course of the inscription can be seen to be even, i.e. the dots composing the loop are fairly evenly spaced; the terminal instantaneous QRS vectors are therefore liberated through normal conducting pathways. This odd flattened-from-top-to-bottom pattern of the spatial QRS loop, as seen in the frontal plane (with or without a marked displacement of the entire QRS loop to the right), was seen in every one of the 8 patients with congenital heart disease with right-sided pathology in this small series. Of these 8 patients, 2 had a Fallot's tetralogy, 2 had auricular septal defects (one with mitral stenosis in addition), 3 had pulmonary stenoses, and one was a 'blue baby' of undiagnosed aetiology.

Case 3

The importance of the above findings may be appreciated in the case of Miss I.L., a young girl who was thought to have suffered a mild bout of rheumatic fever. Her ECG showed an rsR pattern in V_1, not unlike that of the previous patient, but was otherwise normal. Was this incomplete right bundle-branch block, or right ventricular hypertrophy? The SVG is seen in Fig. 3, and shows immediately the crowding together of the dots (time markers), and irregularity of contour, in the terminal QRS loop. These findings confirm that this is (incomplete) right bundle-branch block. This differentiation is impossible on scalar electrocardiography.

Case 4

Mr. L. had classical 'tight' mitral stenosis. The ECG showed the heart to be electrically vertical, with an rsR pattern in V_1, indicative of severe right ventricular hypertrophy, in addition. The SVG (Fig. 4) shows a narrow vertically orientated QRS loop. This pattern is quite characteristic of severe right ventricular hypertrophy in mitral stenosis, as pointed out some

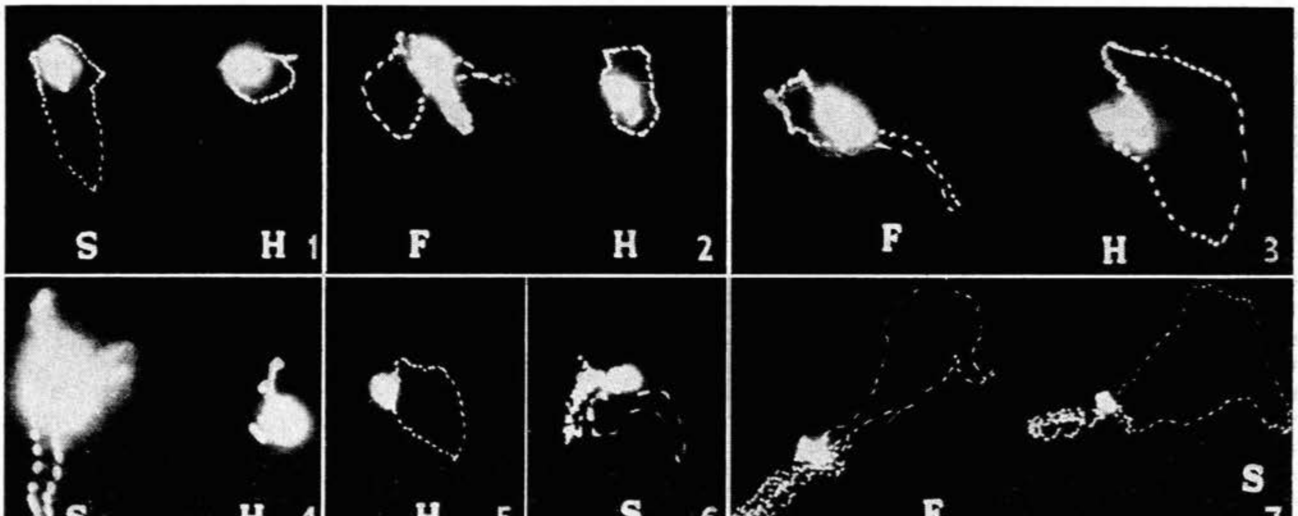

Fig. 1. The prominent white blob marks the iso-electric point. The loop is due to ventricular depolarization (QRS loop). The shape of the dots shows the direction of rotation of the loop to be anti-clockwise in the sagittal plane. There is an abrupt irregularity in the posterior near-terminal portion of the QRS loop; inasmuch as the rest of the loop is smoothly contoured, this must represent a localized fault in ventricular depolarization. The T loop is just visible as a distinct elongation of the iso-electric point downwards and slightly to the left.
Fig. 2. The QRS loop is flattened from top to bottom, and extends as much to the right as to the left of the iso-electric point. The dots (time markers) are evenly spaced; this implies that the accession wave follows normal conduction pathways during ventricular depolarization.
Fig. 3. The shape of the dots shows the direction of rotation of the QRS loop to be clockwise in the frontal, and anti-clockwise in the horizontal plane. The terminal part of the loop is therefore that lying to the right of the iso-electric point. The time markers are abnormally closely approximated to each other there; this implies the presence of abnormal conduction pathways for right ventricular depolarization, i.e. right bundle-branch block.
Fig. 4. The QRS loop is abnormally narrow (as seen in the horizontal and sagittal planes) and is vertically orientated (contrast with Fig. 2).
Fig. 5. The SVG (horizontal plane) in a case of anteroseptal myocardial infarction. The QRS loop maintains its normal clockwise direction of rotation. Note, however, the abnormal initial movement of the loop posteriorly and to the left, instead of anteriorly and to the right. The loop is displaced *away* from the site of the infarction.
Fig. 6. The SVG (left sagittal plane) in infero-posterior infarction. The T loop is curved downwards and lies anteriorly to the QRS loop. The latter is seen to be concave upwards in its inferior limb, i.e. displaced away from the site of infarction.
Fig. 7. The T loop lies anteriorly, inferiorly and to the right of the iso-electric point. The QRS loop extends upwards and to the left. This is the usual pattern in left bundle-branch block. Note the abrupt tongue-like projection on the inferior limb of the QRS loop. This must represent a localized fault in conduction. Is this evidence of myocardial infarction?

years ago.[1] The point to be made is that vectorcardiography can readily distinguish between the rather similar ECGs of congenital heart disease with right ventricular hypertrophy or dilatation, right bundle-branch block, and acquired right ventricular hypertrophy.

DIAGNOSIS OF MYOCARDIAL INFARCTION

A myocardial infarct is dead muscle, and cannot contribute vector voltages to the mean voltages generated by depolarizing ventricular muscle. The SVG, then, will show deviation of the spatial QRS loop *away* from the site of the infarct. Thus, with an anteroseptal infarct, the initial mean instantaneous QRS vectors which normally run anteriorly and to the right, and which represent septal activation, will be absent (*Case 5*, Fig. 5).

Similarly, with a so-called 'posterior' infarction — in reality often an infero-posterior infarction — those vector voltages emanating from anatomically footward-orientated cardiac muscle will be absent; hence apparent upward displacement of the QRS loop (*Case 6*, Fig. 6). In both the above cases, the ECGs clearly showed the infarction, and the SVGs offered no diagnostic advantages.

Burch has put forward the concept that some intramural infarcts, too small to be seen on scalar ECGs, may yet be visible on spatial vectorcardiograms. Fig. 7 shows the SVG of a patient who had suffered what was, clinically, undoubtedly a myocardial infarction a year previously, and had had repeated anginal episodes since. The ECG showed only left bundle-branch block with raised ST segments across the chest leads. It was impossible to say whether these ST segments represented aneurysmal formation or injured muscle, or were merely the concomitants of bundle-branch block.

The SVG shows the upward and leftward sweep of the QRS loop, as usually seen in left bundle-branch block; the smaller projection to the right is the T loop. In addition, the outward limb of the QRS loop shows an odd, tongued projection. This must represent an abrupt alteration in the pathway of the accession wave through the ventricular musculature. Is this evidence of the old infarction? In the absence of a large-scale study with inclusive post-mortem controls, it is at present impossible to answer this question; it will be agreed, however, that findings such as the above are extremely suggestive.

CONCLUSION AND SUMMARY

This paper has dealt, extremely briefly, with some of the variants to be found in the QRS loop in cardiac disease. A study of abnormalities of the P and T loops requires rather more elaborate equipment than that used here.[2,3] The examples given above should be sufficient to suggest that spatial vectorcardiography has a great deal to offer in routine clinical cardiology.

Its main advantages seem to be: (1) As an important conceptual aid in the understanding of scalar ECGs, (2) a unique ability to differentiate right bundle-branch block from right ventricular hypertrophy, (3) the ability to differentiate congenital from acquired right ventricular hypertrophy, and (4) its possible role in the detection of intramural infarction.

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