A Study of the Spatial Vectorcardiogram in Left Bundle Branch Block

By J. Frank Pantridge, M.D., J. A. Abildskov, M.D., G. E. Burch, M.D., and J. A. Cronich, M.S.

A method of vectorcardiography, in which the projections of the spatial vectorcardiogram in various planes of an equilateral tetrahedron reference system are recorded, has been applied to the study of left bundle branch block. Results suggest that the method employed may provide information relative to the state of the myocardium and the extent of myocardial lesions which is not evident from electrocardiographic examination.

Experimental evidence has shown that the electrocardiographic pattern regarded as indicative of left bundle branch block may result from interruption of the left bundle branch by a local lesion. Clinical and pathologic evidence, however, has been presented to suggest that more commonly this electrocardiographic pattern results from diffuse myocardial damage associated with hypertrophy and dilatation of the left ventricle.

The clinical state and the poor prognosis of the majority of patients in whom left bundle branch block is diagnosed indicate that this electrocardiographic abnormality is usually associated with grave myocardial damage. However, a small proportion of patients with this disturbance in conduction show minimal clinical evidence of myocardial disease; it is presumed that in these the bundle branch has been interrupted by a local lesion.

The impossibility of determining by ordinary electrocardiographic methods the extent of a lesion responsible for or associated with left bundle branch block prompted this study of the spatial vectorcardiogram in that condition. It was hoped that by analysis of the spatial vector it might be possible to determine whether the block arose from a generalized abnormality of the conducting tissue or cardiac muscle of the left ventricle, from involvement of the septum by an anterior or posterior myocardial infarct, or from interruption of the bundle branch by a well localized lesion.

Materials and Method

Twenty-eight patients from the wards of the Charity Hospital, whose electrocardiograms had been interpreted as indicative of left bundle branch block, were selected for study. The QRS interval in all cases measured 0.12 second or more, and in 23 cases unipolar leads from the left side of the precordium showed definite delay in the onset of the intrinsicoid deflection. The electrocardiograms of 4 subjects (Subjects 3, 4, 7, and 11) showed QRS intervals of 0.13 to 0.16 second but did not show broad, flat-topped or splintered R waves in the precordial leads. Such tracings represent a special problem of interpretation and are not universally considered to indicate left bundle branch block.

The spatial vectorcardiograms were recorded by the method described by Wilson and Johnston as modified in this laboratory. This method employs as a reference system the equilateral tetrahedron of Wilson. The standard limb electrodes and a back electrode placed approximately 3 cm. to the left of the seventh dorsal vertebral spine were used. The projections of the movement of the spatial vector on the frontal and sagittal planes of the tetrahedron were recorded simultaneously by means of two cathode-ray tubes.

The connections of the cathode-ray tube used to record the frontal vectorcardiogram are similar to those described by Wilson and Johnston. The right and left arm electrodes were connected to the plates of the cathode-ray tube producing horizontal deflections; the plates producing vertical deflections were connected to the Wilson central terminal and to the left foot. The connections were so arranged that relative positivity of the left arm produced a
Table 1.—Clinical Data

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Age (yr.)</th>
<th>Sex</th>
<th>Cardiac Enlargement</th>
<th>B.P.†</th>
<th>Congestive Failure</th>
<th>History of Angina</th>
<th>History Suggesting Coronary Occlusion</th>
<th>Clinical Diagnosis</th>
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<td></td>
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<tr>
<td><strong>Group I</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>M</td>
<td>++</td>
<td>230/75; 148/60</td>
<td>+</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>M</td>
<td>+</td>
<td>108/80</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>M</td>
<td>++</td>
<td>170/90</td>
<td>+</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>72</td>
<td>M</td>
<td>+++</td>
<td>230/110; 188/74</td>
<td>L.V.</td>
<td>-</td>
<td>?</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>5</td>
<td>81</td>
<td>M</td>
<td>+++</td>
<td>180/90</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>57</td>
<td>M</td>
<td>+++</td>
<td>102/86</td>
<td>+</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>76</td>
<td>M</td>
<td>+</td>
<td>150/100</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>F</td>
<td>++</td>
<td>140/40</td>
<td>+</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>9</td>
<td>74</td>
<td>F</td>
<td>+++</td>
<td>185/95</td>
<td>+++</td>
<td>-</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>10</td>
<td>78</td>
<td>M</td>
<td>+++</td>
<td>200/120; 130/90</td>
<td>+++</td>
<td>?</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>11</td>
<td>64</td>
<td>M</td>
<td>+++</td>
<td>190/135; 140/98</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>12</td>
<td>51</td>
<td>F</td>
<td>+++</td>
<td>234/158</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>13</td>
<td>44</td>
<td>F</td>
<td>sl.</td>
<td>250/120</td>
<td>L.V.</td>
<td>?</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>14</td>
<td>64</td>
<td>F</td>
<td>++</td>
<td>160/110</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>74</td>
<td>M</td>
<td></td>
<td>120/75</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A.S.H.D.</td>
</tr>
<tr>
<td>16</td>
<td>48</td>
<td>F</td>
<td>++</td>
<td>190/135</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>H.C.V.D. and A.S.H.D.</td>
</tr>
<tr>
<td>17</td>
<td>64</td>
<td>F</td>
<td>+</td>
<td>134/78</td>
<td></td>
<td>+</td>
<td></td>
<td>A.S.H.D.</td>
</tr>
<tr>
<td>18</td>
<td>60</td>
<td>F</td>
<td>++</td>
<td>105/70</td>
<td>+</td>
<td>+</td>
<td></td>
<td>A.S.H.D.</td>
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<tr>
<td>19</td>
<td>77</td>
<td>M</td>
<td>++</td>
<td>220/110</td>
<td>+++</td>
<td>-</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>20</td>
<td>67</td>
<td>M</td>
<td>+</td>
<td>100/84</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>A.S.H.D.</td>
</tr>
<tr>
<td>21</td>
<td>68</td>
<td>F</td>
<td>+</td>
<td>185/100</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>H.C.V.D. and A.S.H.D.</td>
</tr>
<tr>
<td>22</td>
<td>55</td>
<td>F</td>
<td>++</td>
<td>115/75</td>
<td>+++</td>
<td>-</td>
<td>-</td>
<td>A.S.H.D.</td>
</tr>
<tr>
<td>23</td>
<td>49</td>
<td>F</td>
<td>sl.</td>
<td>230/130</td>
<td>L.V.</td>
<td>+</td>
<td>-</td>
<td>H.C.V.D.</td>
</tr>
<tr>
<td>24</td>
<td>47</td>
<td>F</td>
<td>++</td>
<td>164/110; 124/64</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>H.C.V.D. and A.S.H.D.</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>M</td>
<td>+++</td>
<td>140/90</td>
<td>+++</td>
<td>-</td>
<td>-</td>
<td>A.S.H.D.</td>
</tr>
<tr>
<td><strong>Group IV</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>74</td>
<td>M</td>
<td>sl.</td>
<td>170/90</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Duodenal ulcer</td>
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<tr>
<td>27</td>
<td>65</td>
<td>M</td>
<td>-</td>
<td>155/70</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>Benign prostatic enlargement and H.C.V.D.</td>
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<tr>
<td>28</td>
<td>58</td>
<td>M</td>
<td>sl.</td>
<td>158/96</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Bronchiectasis</td>
</tr>
</tbody>
</table>

* Degree of cardiac enlargement is graded as = no enlargement, sl = slight, + = moderate, ++ = severe, +++ = extreme.
† When two values for blood pressure are given, the first is the highest value recorded in the past and the second the value obtained at the time the vectorcardiogram was recorded. When one value is given, it is that obtained at the time the vectorcardiogram was recorded.
‡ Severity of congestive failure is graded as = none, + = moderate, ++ = severe, and +++ = extreme.
Isolated left ventricular failure is indicated by L.V.
§ H.C.V.D. = hypertensive cardiovascular disease.
‖ A.S.H.D. = arteriosclerotic heart disease.
deflection of the beam to the left (or to the right, as viewed by the observer). The calibration is such that
1 millivolt introduced into the horizontal circuit produces a deflection of the electron beam of 1.0
inch on the oscillographic screen and 1 millivolt introduced into the vertical circuit produces a deflection of 1.7 inches. The cathode-ray tube used to record the sagittal vectorcardiogram was so con-
1ected that horizontal deflections were obtained from the Wilson central terminal and the back elec-
trode, the calibration being 1.2 inches per millivolt. Relative positivity of the back electrode resulted in
movement of the electron beam to the right (as viewed by the observer when facing the sagittal plane from the left). The vertical deflections in this tube were obtained from the Wilson central terminal and the left foot, the calibration being a deflection 1.7 inch per millivolt. Relative positivity of the foot electrode yielded a downward deflection of the beam.

The projection of the locus of the spatial vector onto the superior, right, and left planes of the tetrahedron was also obtained by selecting proper combinations of electrodes. The calibrations used are necessary "standardizing factors" because the potential differences are scalar quantities which are treated as vectors? 

Wire models representing the QRS sE-loops and T sE-loops were constructed from simultaneous photographic records of the frontal and sagittal vectorcardiograms, and the constructions were
checked by records of the projection of the move-
ment of the vector on the superior, right, and left surfaces of the tetrahedron.

Electrocardiograms showing the standard leads, unipolar limb leads, precordial Leads V1 to V6 and Lead Vx were obtained for the majority of subjects at the time of recording of the vectorcardiogram. Electrocardiograms (standard and precordial Leads V1 to V6) of the remainder of the subjects were ob-
tained from the hospital files. The interval between
recording of the electrocardiogram and of the vec-
torcardiogram of these subjects was usually a few
days. Correlation of the electrocardiogram, spatial vectorcardiogram, and clinical features was therefore possible. The clinical features considered most rele-
ant to this investigation are recorded in table 1. Cardiac size and position were confirmed by roent-
genographic examination. When present, enlarge-
mment involved predominantly the left ventricle.

Results

Drawings constructed from tracings of the simultaneously recorded frontal and sagittal vectorcardiograms are illustrated in figures 1 through 4. For purposes of presentation the triaxial reference system was used in the frontal plane. Angles in the sagittal plane are meas-
ured similarly with the ±180 degree axis located anteriorly. The term "axis of the loop" is used to indicate a straight line drawn from the origin of the loop to its most distant point. This bears no constant relationship to the mean electric axis.

With one exception (the frontal plane loop of Subject 26), the projections of the QRS sE-loops on both the frontal and sagittal planes are in-
scribed in a counterclockwise direction. As would be expected from the observed S-T segment shift, the QRS sE-loop failed to return to the isoelectric point, its termination and the initial portion of the T sE-loop being displaced away from the origin. For this reason a closed T sE-loop was not written. The point at which the QRS sE-loops and T sE-loops become continuous was readily recognized on the oscillographic screen by abrupt deceleration of the fluorescent beam. This point of junction is indicated in the illustrations by the letter J.

For purposes of description only the sub-
jects have been divided into four groups on the basis of similarity of the recorded QRS sE-
loops:

Group I. The QRS sE-loops of Subjects 1
through 8 (figs. 1 and 7) tended to enclose a single plane area facing anteriorly and some-
what to the left. The projection on the frontal plane enclosed a wide area located mainly in the first and second sextants of the triaxial reference system and the projection on the sagittal plane a relatively narrow area. Both the axis of the sagittal projection of the QRS sE-loop and that of the frontal axis lay between -30 and -70 degrees. The QRS sE-loops in this group presented a relatively smooth, oval or rounded contour.

Group II. The QRS sE-loops of Subjects 9
through 14 (figs. 2 and 7, Subject 11) were elongated and directed upward, backward, and to the left. The areas enclosed by their projection on both the frontal and sagittal planes were small. The axis of the frontal projection lay between -30 and -70 degrees and that of the sagittal projection between -40 and -45 degrees.

The majority of the spatial QRS sE-loops in this group presented an irregular contour.
Fig. 1.—Group I: QRS sE-loops and T sE-loops of Subjects 1 through 8.

Fig. 2.—Group II: QRS sE-loops and T sE-loops of Subjects 9 through 14.

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Fig. 3.—Group III: QRS sE-loops and T sE-loops of Subjects 15 through 25.
Fig. 4.—Group IV: QRS sÉ-loops and T sÉ-loops of Subjects 23 through 28.

Fig. 5.—QRS sÉ- and T sÉ-loops of two patients with gross left ventricular hypertrophy.

Fig. 6.—QRS sÉ- and T sÉ-loops of two normal subjects.
Those of Subjects 10, 11, 12, and 14 were rotated on their longitudinal axis and did not, therefore, enclose a single plane area.

Group III. The QRS sE-loops of Subjects 15 through 25 (figs. 3 and 7, Subject 18) were directed backward and to the left. The axis of the frontal projection lay between +70 and −70 degrees, that of the sagittal projection between +20 and −60 degrees. Many of the QRS sE-loops in this group showed extensive indentations or irregularities, especially on the long limbs, and it was largely on this basis that these were classified together. The QRS sE-loops of Subjects 22, 23, and 24 were projected almost directly backward and enclosed a wide, roughly rectangular plane area so rotated that the left surfaces were directed slightly upward. With the exception of these three subjects the projections of the QRS sE-loops on the frontal and sagittal planes enclosed approximately equal areas. The contour of the QRS sE-loops in this group were irregular or angular.

Group IV. The QRS sE-loops of Subjects 26, 27, and 28 (figs. 4 and 7, Subject 26) were elongated and differed greatly from those of the other groups in their downward direction. The axis of the frontal projection lay between +70 and +80 degrees, that of the sagittal projection between +60 and +100 degrees. Both projections encompassed relatively small areas. The QRS sE-loops of Subject 26 enclosed a plane area, presented a smooth contour, and resembled closely in character and direction that of the normal vectorcardiogram.

Discussion

The known variability of the extent and distribution of the pathologic changes associated with left branch block and the impossibility of pathologic correlation, except in 2 subjects, make it difficult to draw from this study more than tentative conclusions. The spatial vectorcardiographic pattern in the subjects of Group I and that in subjects with clinical and electrocardiographic evidence of left ventricular hypertrophy exhibited a striking resemblance (figs. 1, 5, and 7, Subjects 7 and A1). Figure 5 shows the frontal and sagittal projections of the QRS sE and T sE-loops of 2 subjects with severe left ventricular hypertrophy. The similarity between these spatial loops and those of the subjects in Group I suggests that in some cases an electrocardiographic pattern interpreted as indicative of left branch block may in fact represent an expression of severe left ventricular hypertrophy. In this connection it may be noted that in Subject 7 of Group I, in whom death occurred from bronchial carcinoma, the only cardiac abnormality found at autopsy was hypertrophy and dilatation involving particularly the left ventricle, although detailed serial sections of the region of the left bundle branch were not obtained.

With one exception (Subject 13) the subjects in Group II showed severe to extreme cardiac enlargement and evidence of moderate to severe chronic congestive heart failure. The QRS sE-loops of these subjects enclosed a much narrower area and had a more irregular contour than those of the subjects in Group I. It would seem that these characteristics of the loops are most likely to arise from presence of diffuse myocardial damage.

Group III is of particular interest in that three of the subjects in this group had exhibited a clinical syndrome typical of coronary occlusion. The pattern of the QRS sE-loops of these subjects was similar to that which might be expected to result from failure of the anterior or anterolateral surface of the left ventricle to contribute to the formation of these spatial loops. The movement of the efferent portion of the QRS sE-loop in Subjects 18, 20, 24, and 25, resulting in the appearance of Q waves in Leads I or V\textsubscript{h} of the conventional electrocardiogram, suggests the probability of infarction of the septum as well.

The clinical state of the subjects in Group IV differed greatly from that of the subjects in the other groups. In the subjects of Group IV, cardiac enlargement was slight or absent, and there was no evidence of congestive failure. The QRS sE-loops of these subjects, as indicated previously, tend to resemble those of normal subjects.

The QRS sE-loop of Subject 26 in this group differed from the normal only in its rate of inscription and failure to return to the isoelectric point (fig. 4). This patient died following
Fig. 7.—Stereoscopic photographs of wire models representing QRS sЕ-loops and T sЕ-loops. (See text.)

Fig. 8.—Electrocardiograms of subjects whose QRS sЕ-loops and T sЕ-loops are shown in figure 7.
the occurrence of a massive hemorrhage from a duodenal ulcer, and postmortem examination revealed diffuse, patchy interstitial fibrosis, particularly of the septum. Only slight coronary sclerosis and slight left ventricular hypertrophy were present. It seems probable that in this patient bundle branch block arose from a local lesion.

For purposes of comparison the frontal and sagittal projections of the QRS sE\-loops and T sE\-loops of two normal subjects are presented in figure 6 and in figure 7, Subject A. In both of these subjects the projection on the frontal plane of the QRS sE-loop moved in a clockwise direction and the projection on the sagittal plane counterclockwise.

Photographs of the wire models of the QRS sE- and T sE-loops of a representative subject from each group are shown in figure 7. These may be viewed stereoscopically by placing a card between a pair and moving the page slowly toward or away from the eyes until a three-dimensional effect is obtained. The QRS sE- and T sE-loop models of a subject with left ventricular hypertrophy and those of one of the normal subjects are also shown. The electrocardiograms of these selected subjects, with the exception of the normal, are shown in figure 8.

SUMMARY

The spatial vectorcardiographic pattern in twenty-eight subjects with electrocardiographic evidence of left bundle branch block is described. The wide variation in this pattern was noted, and the subjects were divided into four groups on the basis of similarity of the QRS sE-loops.

The spatial vectorcardiographic pattern of one group (Group I) resembled that of some subjects with severe left ventricular hypertrophy. Postmortem examination of one patient from this group revealed hypertrophy and dilatation affecting particularly the left ventricle.

In another group (Group II) the QRS sE-loops enclosed a narrow irregular area, and most of the subjects showed extreme cardiac enlargement and moderate to severe congestive heart failure. It is suggested that the pattern of the loops in this group is consequent to gross diffuse myocardial damage.

The QRS sE-loops of the subjects in Group III were characterized by extreme irregularities such as might be expected if a myocardial infarct were present. The clinical histories of three of these subjects were compatible with myocardial infarction.

Three subjects with minimal clinical evidence of cardiac disease presented QRS sE-loops which were similar in direction to those of normal subjects. One of these loops was also similar in contour to normal vectorcardiograms and at autopsy minimal evidence of cardiac disease was found.

This study offers suggestive evidence that spatial vectorcardiography may provide information relative to the cardiac status of patients with the electrocardiographic pattern of left bundle branch block which is not obtainable with conventional electrocardiograms.

REFERENCES


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