Vectorcardiographic study of QRS loop in patients with left superior axis deviation and right bundle-branch block

H. Kulbertus, P. Collignon, and L. Humblet

From the Section of Cardiology, Department of Internal Medicine, University of Liège
School of Medicine, Liège, Belgium

Thirty-four elderly patients with right bundle-branch block and left axis deviation were studied vectorcardiographically utilizing the McFee-Parungao system. Atherosclerosis, arterial hypertension, angina pectoris, cardiac enlargement, and heart failure were common clinical features in this series. Moreover, intermittent advanced degree of atrioventricular block was present in 10 out of the 34 patients.

The vectorcardiograms might be readily classified into two basic patterns, types A and B. In type A (19 cases), the frontal plane loop was open-faced. The initial vectors were directed anteriorly, inferiorly, and to the right. The mid-temporal vectors were located in the left postero-superior octant, and the late portion of the loop was inscribed anteriorly to the right with conspicuous conduction delay. Those vectorcardiographic features associate the characteristic patterns of left superior intraventricular block with complete right bundle-branch block.

The type B vectorcardiograms (15 cases) demonstrated anterior clockwise loops in the horizontal plane and superior counterclockwise loops in the frontal plane. From a review of the published reports and from personal data, the authors assume that both vectorcardiographic patterns may result from an abnormal spread of excitation resulting from bilateral branch conduction disturbances.

The electrocardiographic association of left axis deviation in limb leads and right bundle-branch block in chest leads, also known as the variant type of right bundle-branch block, has been shown pathologically (Lenègre, 1957; Unger et al., 1958; Lenègre, 1964; Lepeschkin, 1964; Sugiuara et al., 1969) and experimentally (Watt et al., 1968; Rosenbaum, 1968) to be one of the manifestations of bilateral conduction disturbances and one of the most common forerunners of complete heart block (Lenègre, 1957, 1964; Slama et al., 1966; Lasser, Haft, and Friedberg, 1968; Rosenbaum, 1968; Kulbertus and Collignon, 1969; Rothfeld et al., 1969; McClanahan, 1969).

The various electrocardiographic and pathological alterations associated with this pattern have been extensively reviewed, but studies concerning the corresponding vectorcardiographic features still remain very few (Castellanos et al., 1966; Saltzman, Linn, and Pick, 1966; Testoni, Narbone, and Tommaselli, 1968; Rothfeld et al., 1969; Massie and Walsh, 1969).

The present paper is concerned with the vectorcardiographic findings in 34 patients whose electrocardiogram showed left axis deviation with right bundle-branch block.

**Methods**

Spatial vectorcardiograms were recorded using the McFee-Parungao axial system (McFee and Parungao, 1961). The frontal, horizontal, and left sagittal plane loops as well as the scalar tracings X, Y, and Z were photographed with a polaroid camera. For better delineation of early forces, a fivefold amplification of the isolated QRS loop was also recorded. Timing of the various points of the loop was obtained by counting dots on the photograph from the onset of QRS.

Since inaccuracies of timing due to haziness around the E point are inherent in this method of determining instantaneous vectors, the determinations were checked with the scalar tracings such that the three planar instantaneous vectors of the same timing coincided with one another in their co-ordinates.

The duration of the QRS loop was measured and the direction and voltage of the 10, 20, 30, 40, 50, 60, and 90 msec. vectors were determined in each of the three projection planes. The measurements of vector angles in each plane were made with a frame of reference in which the
right of the abcissa was taken as $0^\circ$ and the inferior and superior directions of ordinate were $+90^\circ$ or $-90^\circ$, respectively. Statistical analyses of linear magnitudes were made by standard methods. For the treatment of angular data, the procedure suggested by Downs et al. (1956) was used. Among other advantages, this method avoids any difficulty inherent in the numerical discontinuity point at $\pm 180^\circ$. The prevalent direction ($\bar{A}$) of each timed vector was determined. In order to test whether the clustering of the individual points about the prevalent direction might be considered as statistically significant, a $\chi^2$ value was calculated for each calculated prevalent direction. Furthermore, where it was wished to test the hypothesis that two samples of spatial directions come from the same population, an $F$-test was used according to the recommendation of Watson and Williams (1956).

**Patients**

Patients have been selected on the basis of routine analysis of the daily electrocardiograms recorded in our department.

The following electrocardiographic criteria inspired from those proposed by Lasser et al. (1968) were used for selection of the patients. (1) Total QRS duration of at least 100 msec.; (2) deviation of the mean QRS axis to the left and superior of $-30^\circ$ in the frontal plane; (3) presence of a small initial r wave in leads II, III, and VF; (4) morphology of the QRS complexes consistent with right bundle-branch block, i.e. late R wave in V3 R and V1 and late S in V6.

Patients with acute myocardial infarction or congenital heart disease were not included. Likewise, whenever intermittent complete heart block was disclosed, the QRS loop was analysed only during periods of supraventricular conduction.

The present series consists of 34 patients (23 male, 11 female), ranging in age from 45 to 86 years, with an average of 68. They were all clinically evaluated in our department and the clinical features are listed in the Table.

**Results**

Analysis of the 34 vectorcardiograms revealed that the tracings might be readily classified into two basic patterns which for descriptive purposes will be designated as types A and B. The characteristic distinguishing features of these two types were found mainly in the horizontal and sagittal projections.

In type A, the QRS loop was distributed often to an equal extent between the anterior and posterior hemispheres; the horizontal loop was inscribed counterclockwise. In type B, the QRS loop was projected anteriorly and the horizontal loop turned mostly clockwise.

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<th>TABLE Summary of clinical features</th>
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<td>No. of cases</td>
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<td>Mean age (yr.)</td>
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<td>Male</td>
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<td>Female</td>
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<td>Dyspnoea (at least type II B)</td>
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<td>Congestive heart failure</td>
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<td>Arterial hypertension</td>
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<td>Angina pectoris</td>
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<td>Adams-Stokes syndrome with</td>
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<td>permanent AV block (complete)</td>
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<td>Syncope and dizziness without</td>
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<td>evidence of AV conduction disturbance</td>
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<td>Cardiac enlargement</td>
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<td>Atherosclerosis of aorta</td>
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<td>Rheumatoid arthritis</td>
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**Description of type A vectorcardiograms** (Fig. 1 and 2) Nineteen cases were included in type A. The mean total duration of the QRS complexes was 121 msec. $\pm 21$. The frontal plane loop was open-faced and inscribed counterclockwise in all cases. The initial vectors (10 msec.) were nearly always directed anteriorly, inferiorly, and to the right. The efferent limb proceeded horizontally to the left. Between 30 and 50 msec., the loop swung superiorly and the mid-temporal vectors were located in the left superior quadrant. The Y axis was then crossed and the loop finally showed a slowly inscribed terminal appendage directed to the right.

The horizontal plane loop was inscribed counterclockwise for its major portion in all cases. It showed initial deflection (10 msec.) directed anteriorly and nearly always to the right. The efferent limb was inscribed to the left and anteriorly until 30 to 50 msec. The loop then passed posteriorly with mid-temporal vectors located in the left posterior quadrant. The terminal portion of the loop showed a finger-like, slowly inscribed appendage directed anteriorly and to the right. The direction of inscription of this appendage was counterclockwise in 7 cases and clockwise...
in 12. The left sagittal plane loop was inscribed clockwise in 8 cases, counterclockwise in 7, and showed a figure-of-eight configuration in 4 instances. The initial vectors (10 and 20 msec.) were directed anteriorly and nearly always inferiorly. The mid-temporal vectors were located in the postero-superior quadrant. A slowly inscribed terminal portion oriented anteriorly was observed in all cases.

Statistical analysis of the type A tracings (Fig. 2) indicated a significant degree of clustering for each timed vector in the frontal, horizontal, and left sagittal projections ($p < 0.01$).

Description of type B vectorcardiograms (Fig. 3 and 5) Fifteen cases were included in type B. The average total QRS duration was 132 msec. ± 22, a value that was not significantly different from that observed in type A ($0.50 > p > 0.40$).

The frontal plane loop was inscribed counterclockwise in all cases. The over-all shape of the loop was open-faced in 10 cases and more elongated in 5. The initial vector (10 msec.) was directed inferiorly and to the left in all but one case where the 10 msec. vector was directed inferiorly to the right. The efferent limb moved first leftward and then swung superiorly. The mid-temporal vectors were located in the left superior quadrant. The afferent limb was inscribed to the right, the latter segment of the loop displaying conduction delay.

The horizontal plane loop was clockwise inscribed in all but three cases where a figure-of-eight configuration was seen. The very beginning of the loop was slightly posterior in 5 cases, but the 10 msec. vector was generally located anteriorly and to the left. The efferent limb occupied the left anterior quadrant. The terminal portion displaying conspicuous conduction delay was inscribed in the right hemicircle.

The sagittal plane loop turned clockwise for its major portion. The initial vectors (10 msec.) were inferiorly directed. The

**FIG. 1** A 53-year-old woman with atherosclerosis and angina pectoris. The loop is interrupted every 1/400 sec.; calibration 500 μV.

**FIG. 2** Range of direction and prevalent direction of the various timed vectors in the frontal, horizontal, and left sagittal plane loops of the vectorcardiograms in type A. To be noted that, in the left sagittal plane, the 40 msec. vector was located in the superior hemicircle (0° to +175°) in all but one case where it fell at +95°. The latter point was not taken into account for the calculation of the prevalent direction.
The efferent limb proceeded anteriorly and superiorly. After it had reached its maximally superior extent, the loop started to descend gradually, and the late portion of the QRS was inscribed in a counterclockwise direction with delayed conduction.

In 5 cases the conduction slowing did not appear to be limited to the preterminal and terminal forces but involved most of depolarization. The QRS duration of these 5 cases was 145 msec. ±25 and the frontal plane loop was narrow and elongated with the main body lying between −75° and −90° (Fig. 4).

Statistical analysis of the type B tracings (Fig. 5) showed a significant degree of clustering for all timed vectors. In the frontal, horizontal, and left sagittal projections $p < 0.01$ or $0.05$.

The prevalent direction in type B was significantly different ($p < 0.01$) from that observed in type A for the following timed vectors: 10 msec. in the frontal plane; 10, 40, 50, and 60 msec. in the horizontal plane; 50 and 60 msec. in the left sagittal plane. For the remaining timed vectors, no significant difference could be statistically demonstrated.

**Associated clinical features** The associated clinical observations are listed in the Table. Patients in this study were elderly, all but five of them being over 60 years of age. Dyspnoea, cardiac failure, and angina pectoris were frequent admission complaints. Likewise, atherosclerosis with calcification of the ascending aorta, radiological evidence of cardiac enlargement (cardiothoracic ratio greater than 0.50), arterial hypertension with diastolic pressure higher than 100 mm. Hg, systolic murmur at the base of the heart, and peripheral vascular disease were the most common associated clinical features.

While the number of cases with documented history of myocardial infarction was small, the high incidence of Adams-Stokes syndrome with electrical evidence of atrioventricular conduction disturbances was notable (10 out of 34 cases).

None of our patients had definite radiological signs of right ventricular enlargement in either the postero-anterior or oblique positions.

From the listed data, it appeared and was confirmed by statistical analysis, that the incidence of angina pectoris, arterial hypertension, atherosclerosis of the ascending aorta, cardiac enlargement, cardiac systolic murmur, and Adams-Stokes syndrome was not different from one group to the other.
On the other hand, it seemed at first sight that the age as well as the frequency of congestive heart failure and dyspnoea were increasing from group A to group B. However, the numbers of reported patients were too small for any definite conclusion to be drawn, and comparison of group A with group B showed that the observed differences did not reach the 5 per cent level of significance.

**Discussion**

Wilson, Johnston, and Barker (1934) first called attention to the electrocardiographic syndrome of right bundle-branch block associated with conspicuous left axis deviation. Along with two other possible explanations, the quoted authors advanced the hypothesis that this electrocardiographic combination might result from block of the anterior fascicles of the left bundle-branch together with block of the right bundle-branch.

Subsequent investigations provided evidence to support this latter interpretation. Thus, histopathological examination of the conduction system in patients presenting with right bundle-branch block and left axis deviation revealed complete or nearly complete interruption of the right bundle-branch with conspicuous involvement or nearly complete interruption of the left bundle-branch (Lenègre, 1957; Unger et al., 1958; Lenègre, 1964; Lepeschkin, 1964; Harris et al., 1969).

Moreover, different authors have reported that patients giving evidence of this electrocardiographic association frequently develop complete heart block (Lenègre, 1957, 1964; Lepeschkin, 1964; Slama et al., 1966; Lasser et al., 1968; Rosenbaum, 1968; Kullertus and Collignon, 1969; Rothfeld et al., 1969; Watt and Pruitt, 1969; McClenahan, 1969). This feature was consistent with the proposed hypothesis since, in such cases, the atrioventricular conduction was supposed to rely on the integrity of a very limited number of His bundle fibres.

Finally, recent experiments showed that the electrocardiographic pattern of right bundle-branch block with left axis deviation might be obtained in both canine and primate hearts by sectioning the right bundle-branch after having interrupted the anterior fibres of the left bundle-branch by means of a ligation (Rosenbaum, 1968; Watt et al., 1968).

From all these data, it seems now generally agreed that the association of right bundle-branch block with left axis deviation is one of the electrocardiographic manifestations of bilateral bundle-branch block.

The electrocardiographic details of this combination have been thoroughly studied and classified. Nevertheless, studies of the corresponding vectorcardiographic patterns remain heretofore very few (Castellanos et al., 1966; Saltzman et al., 1966; Testoni et al., 1966; Rothfeld et al., 1969; Massie and Walsh, 1969).

Testoni et al. (1968) reported 23 cases of right bundle-branch block with left axis deviation. All their tracings would fall into our group B, while Rothfeld et al. (1969) studied 11 vectorcardiograms which all had the characteristic features of our group A. Owing to differences in the selection criteria, those two series are not directly comparable with the present group.

On the contrary, Saltzman et al. (1966) in a study of 23 patients proposed a classification which inspired the present one. Their
type A is identical to our group A and their type B tracings show anterior clockwise horizontal plane loop as in our group B cases. It should nevertheless be noted that some of their tracings referred to as characteristic of type B showed electrocardiographic and vectorcardiographic signs of inferior infarction, a feature that was never present in our patients.

The vectorcardiographic aspect in type A associates the previously described features of the left superior intraventricular block (Kulbertus, Collignon, and Humblet, 1970) with the well-known terminal appendage characteristic of right bundle-branch block. The interpretation of these tracings seems therefore straightforward.

The interpretation of the type B vectorcardiograms and more particularly of the anterior clockwise horizontal plane loop is less clear cut.

In view of similarities with the vectorcardiographic alterations following an infarction of the true posterior wall of the left ventricle (Hugenholtz, Forkner, and Levine, 1961; Walsh et al., 1962), Saltzman et al. (1966) suggested that it was possible to indirect additional fibrosis and or infarction of the posterior wall as a direct causative factor that might account for the differences in the horizontal plane between type A and B. The same interpretation was also put forward by Rothfeld et al. (1969).

In our opinion, the anterior displacement might be interpreted as a direct consequence of the conduction disturbances, and lesions of the posterior wall of the left ventricle are not a prerequisite for the genesis of the type B vectorcardiogram.

Experimental evidence supporting this hypothesis may be found in a recent work where interruption of anterior fibres of the left bundle-branch system was produced together with right bundle-branch block in canine and primate hearts (Watt et al., 1968). The authors observed that rapid conduction into the ventricles could then proceed only over posterior fascicles of the left bundle-branch. This resulted in a relatively early island of epicardial excitation of the posterior wall of the left ventricle followed by progressive envelopment of both left and right ventricles in such a way that excitation times were progressively later at points more and more distant from the posteriorly located initial site of excitation. In such conditions, it may be rationally postulated that the vectorcardiographic loop must be displaced anteriorly.

Moreover, it has also been shown that patterns of right bundle-branch block with left axis deviation and clockwise horizontal plane loop were sometimes intermittent (Case 3) and could be produced in normal hearts by introduction of atrial premature beats resulting in aberrant ventricular conduction (Cohen et al., 1968).

In order to provide further substantiation to the hypothesis that the association of right bundle-branch block with left axis deviation and anterior clockwise horizontal plane loop may be a direct consequence of alteration in the spread of excitation, with posterior precedence, experiments were conducted in which artificial stimulation of the posterior wall of the left ventricle was produced in patients undergoing abdominal surgical procedures. Bipolar electrodes were applied through the diaphragm onto the postero-diaphragmatic region of the left ventricular wall. Stimuli were delivered between 500 and 700 msec after onset of the preceding QRS by means of an R wave coupled pulse generator (Medtronic model 5837). The resulting beats showed vectorcardiographic loops similar to those described as type B in the present paper (Fig. 6): a superiorly displaced counter-clockwise frontal plane loop was obtained along with an anterior clockwise horizontal plane loop.

It is therefore concluded that the combination of left axis deviation with right bundle-branch block associated with anterior and clockwise horizontal loop is not necessarily indicative of extensive myocardial disease with pathological alteration of the posterior wall of the left ventricle, and that it may

**FIG. 6 Vectorcardiographic loops obtained during artificial stimulation applied onto the epicardial surface of the postero-diaphragmatic wall of the left ventricle at about 4 cm from the apex. The patient was a 23-year-old woman with a normal heart who underwent splenectomy for haemolytic anaemia.**
result from an abnormal pattern of excitation in bilateral branch conduction disturbances.

The precise reasons for the differing vectorcardiographic patterns remain heretofore unknown and deserve further study. They are likely to be related to variation in both location and extent of the lesions involving the right and the left bundle-branch system, respectively. It is tempting to consider that there is a gradation from group A to group B indicating progressing damage to the conducting system (Saltzman et al., 1966), but this hypothesis is admittedly purely speculative and must await further substantiation.

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