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Vectorcardiographic study of aberrant conduction[1]
Anterior displacement of QRS: another form of intraventricular block

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Aberrant ventricular conduction was induced in 44 subjects by introduction of atrial premature beats through a transvenous catheter-electrode. Multiple patterns of aberrant ventricular conduction were obtained in 32 patients and, in the whole group, 116 different configurations were recorded. Of these, 104 showed a classical pattern of mono- or biventricular conduction disturbance. The pattern frequencies were as follows: right bundle-branch block, 28; left anterior hemiblock combined with right bundle-branch block, 21; left anterior hemiblock, 17; left posterior hemiblock combined with right bundle-branch block, 12; left posterior hemiblock, 10; complete left bundle-branch block, 10; and incomplete left bundle-branch block, 6. The remaining 12 configurations could not be classified into the usual categories of intraventricular blocks. In 7 of them, the alterations only consisted of trivial modifications of the QRS contour. In the other 5 instances, aberrant conduction manifested itself by a conspicuous anterior displacement of the QRS loop, with increased duration of anterior forces. The latter observation is worthy of notice, as it indicates that, in the differential diagnosis of the vectorcardiographic pattern characterized by prominent anterior forces, conduction disturbances should be considered a possible aetiological factor in addition to right ventricular hypertrophy, and true posterior wall myocardial infarction.

Introduction of atrial premature beats through a transvenous catheter-electrode has been used in human beings in order to produce aberrant ventricular conduction (Cohen *et al.*, 1968; Kulbertus *et al.*, 1971; Kulbertus, 1972; Wu *et al.*, 1974). The data from these experiments enabled the authors to describe the vectorcardiographic features of different conduction defects in their pure intermittent form (Cohen *et al.*, 1968; Kulbertus, 1972) and to investigate their influence on various pathological vectorcardiographic manifestations (Cohen *et al.*, 1968; Kulbertus *et al.*, 1971; Kulbertus, 1972).

The present report is concerned with the observations made in 44 subjects by delivering premature atrial stimuli throughout the diastolic period. Attention will be drawn towards an unusual variety of conduction disturbance, with conspicuous anterior displacement of the QRS.

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Patients and methods

Studies were made on 44 patients (30 men and 14 women) with normal sinus rhythm whose ages ranged from 14 to 71, with an average of 51. Among the 44 investigated, 2 were normal subjects. Eight patients had arterial hypertension, 3 chronic airways obstruction, 13 peripheral vascular disease, and 14 coronary heart disease. Eleven of the 14 with coronary heart disease had a history of previous myocardial infarction diagnosed on the basis of suggestive clinical signs, with typical electrocardiographic abnormalities at the time of the acute episode. The remaining subjects had valvular lesions (12 cases), congenital malformations (2 cases), or hypertrophic obstructive cardiomyopathy (1 case).

The classification based on the control electrocardiographic tracing included 10 subjects with normal electrocardiograms, 11 patients with residua of myocardial infarction, 12 patients with left anterior hemiblock (once combined with right

TABLE *Patterns of aberrant conduction induced by atrial extrastimuli in 44 patients*

Case No.	Age (yr)	Left anterior hemiblock	Left posterior hemiblock	Left bundle-branch block Complete	In-complete	Complete right bundle-branch block*		Left anterior hemiblock and complete right bundle-branch block*		Left posterior hemiblock and complete right bundle-branch block*		Unclassified patterns Anterior shift	Others
						A	B	A	B	A	B		
Normal electrocardiograms													
1	47	3					3		1				1
2	48							1					1
3	52						2						
4	22		1	1									
5	14						2					1	
6	59		3	1						1			
7	60						1		1		1	1	1
8	53						1					1	
9	45					1	2						
10	48								1				1
Left anterior hemiblock													
11	70	1							1				
12	63							1					
13	67	1				1							
14	59	1											
15 (+RBBB)	65							1		1			
16	66	2		1									1
17	55							1				Normal electrocardiogram	
18	58	1		1	1			1	1				
19	63	2			1								
20	62+A† inf.											1	1
21	41					1		1	1				
22	31					2							
Left ventricular hypertrophy													
23	36									2			
24	39										1		
25	33							1					
26	35		2								1		
27	35		1	2		2		1	1	1			
Right ventricular hypertrophy													
28	59					1	1						
29	34		1							1			
30	36						1						
31	52							1					
32	44						1						
33	46				1						1		
Myocardial infarction													
34	67 (PD)‡	1											
35	71 (PD)	1											
36	60 (PD)		1				1						
37	56 (PD)		1		1						1	1	
38	53 (PD)	1			1		1		2				
39	68 (PD)	2		1	1	1			1				1
40	54 (PD)	1											
41	45(A+PD)			1		1				1			
42	48 (A)			1									
43	70 (A)			1		1			1				
44	54 (A)						1		1				
Total (patients)		12	7	9	6	9	12	9	11	6	5	5	7
(morphologies)		17	10	10	6	11	17	9	12	7	5	5	7
				16		28		21		12		12 +1N	

*See text for description of types A and B.
†A: anterior.
‡PD: posterodiaphragmatic.
The location of the infarcted area was determined on the basis of the electrocardiographic changes at the time of the acute episode.

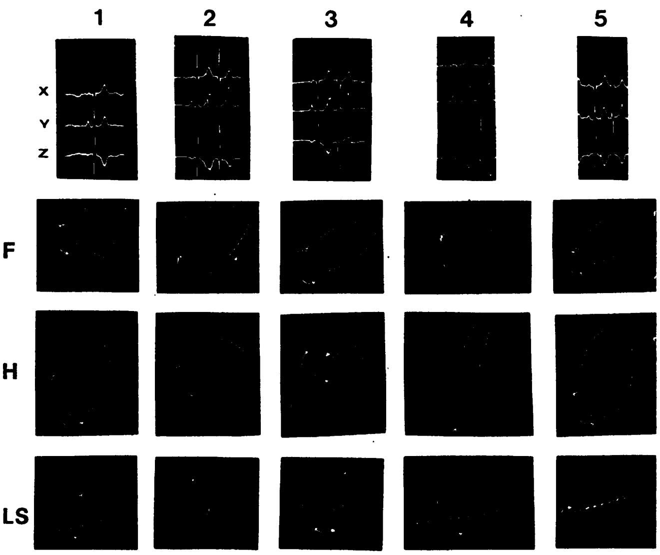

FIG. 1 *Tracings obtained from man aged 47, with peripheral vascular disease and normal resting electrocardiogram. First picture (1) shows control tracing; other four, various aberrantly conducted beats; 2: left anterior hemiblock; 3: left anterior hemiblock with right bundle-branch block; 4 and 5: two other variants of left anterior hemiblock, with possibly, some degree of incomplete left bundle-branch block. The loops are interrupted every 1·25 ms. Calibration: 0·5 mV.*

bundle-branch block), 6 patients with right ventricular hypertrophy, and 5 with left ventricular hypertrophy.

All these patients were studied during cardiac catheterization or during investigation for coronary artery disease. Informed consent was obtained in each case.

An electrode-catheter was pushed through the brachial vein into the right atrium. By means of an R wave coupled pulse generator (Medtronic Model 5837), atrial stimuli were delivered throughout the diastolic period at 5- to 10-ms intervals. Spatial vectorcardiograms were recorded using the McFee-Parungao axial system (1961) by means of a Hewlett-Packard 1520 A vectorcardiograph. The X, Y, and Z scalar leads were recorded on a magnetic tape (HP Instrumentation recorder 3960 A) at a speed of 19 cm (7½ in) per min. They were later reproduced in linear and loop modes on an oscilloscope and photographed by means of a Polaroid camera.

The diagnosis of complete or incomplete left and right bundle-branch block was made according to currently agreed criteria (Chou, Helm, and Kaplan, 1974). For the purposes of description and in the presence of right bundle-branch block, a distinction was made between types A and B (Kulbertus, Collignon, and Humblet, 1970a), type A being characterized by a counterclockwise horizontal plane loop and type B by an entirely anterior and clockwise rotated loop in the transverse projection.

The existence of left anterior hemiblock was recognized by means of previously described morphological characteristics (Kulbertus, Collignon, and Humblet, 1970b; Benchimol, Barreto, and Pedraza, 1971; Chou *et al.*, 1974). Left posterior hemiblock was diagnosed only by comparison with the control tracing. It was thought to be present when the following changes occurred: (1) inferior axis shift (whatever its importance); (2) displacement of the initial forces towards the left, anterior and superior octant; and (3) displacement of the midtemporal and late vectors towards the right inferior, and posterior octant (Rosenbaum, Elizari, and Lazzari, 1970; Kulbertus, 1972). Finally, the diagnosis of anterior displacement of QRS was made when the portion of the horizontal loop located anterior to the X axis exceeded 70 per cent of the total loop area and when the duration of anterior forces was greater than 50 ms (Chou *et al.*, 1974).

Results

Multiple patterns of aberrant conduction were obtained in 32 out of the 44 patients. On the whole,

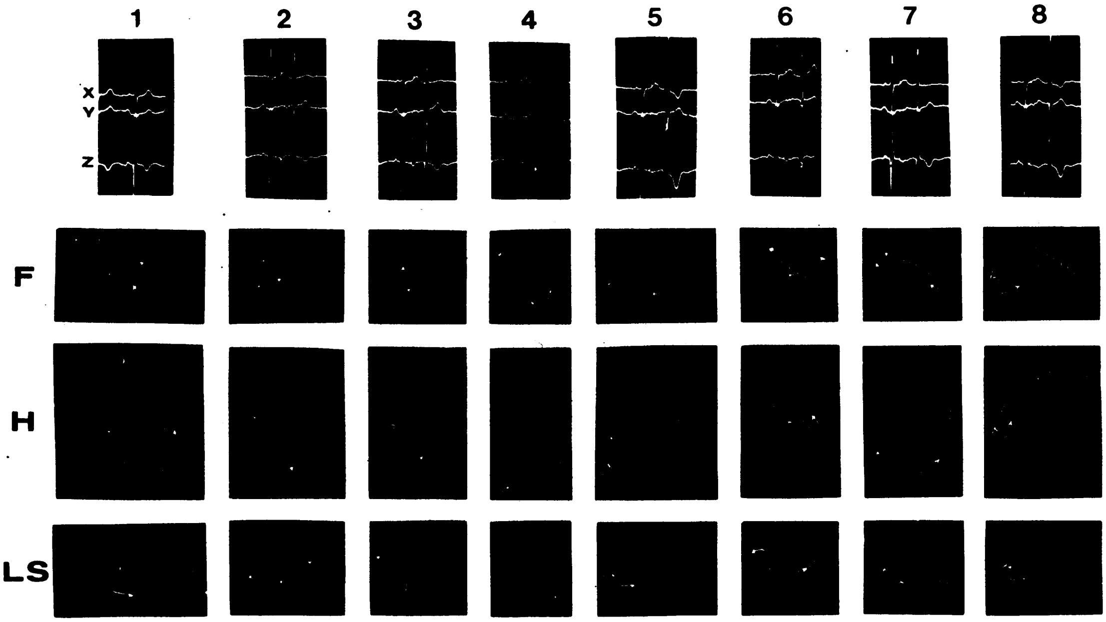

FIG. 2 *Tracings obtained from woman aged 68 with history of previous inferior infarct (10 years before). 1: control tracing. Sequelae of previous infarct are inconspicuous; 2 and 3: left anterior hemiblock with signs of concomitant inferior infarct; 4: left anterior hemiblock with right bundle-branch block and signs of inferior infarct; 5: complete left bundle-branch block; 6: complete right bundle-branch block; 7: slight modification of QRS with attraction of both efferent and afferent limbs towards left posterior quadrant and development of a concavity from anterior occurring from 15 to 30 ms (slight degree of incomplete left bundle-branch block ?); 8: posterior displacement of efferent limb with clockwise rotation of initial portion of QRS compatible with incomplete left bundle-branch block. Loops are interrupted every 1·25 ms. Calibration: 0·5 mV.*

116 different configurations were produced. Of these, 104 showed the typical morphology of one of the classical categories of mono- or bilateral conduction disturbances. The remaining 12, though obviously different in shape from the control vectorcardiogram, could not be readily classified into the usual categories of intraventricular conduction defects. The results from each case are presented in the Table, together with the pattern frequencies. Illustrative examples are shown in Fig. 1, 2, 3, and 4.

Left anterior hemiblock

In 4 cases, several morphologies compatible with the diagnosis of left anterior hemiblock were induced in the same patient (Fig. 1). They differed from one another by the degree of axis shift, the direction of the initial forces, and small variations of the QRS morphology and/or duration.

Twelve patients with pre-existing typical left anterior hemiblock were subjects in this experiment. Their control tracings all showed initial forces pointing anteriorly, inferiorly, and to the right. In one of these cases, the ventricular complexes that followed atrial premature stimulation resumed a normal QRS configuration. A pattern of isolated right bundle-branch block developed in three other instances, whereas 8 patients showed aberrantly conducted beats with left anterior hemiblock and right bundle-branch block (5 types A and 3 types B). Finally, in 6 of these cases, a variant of the left anterior hemiblock morphology was induced; the variations, though small, consistently showed the same features, i.e. a trivial QRS prolongation with widening of the frontal plane loop and leftward shift of the initial forces (Kulbertus, 1975).

Left posterior hemiblock

In 7 cases, the atrial premature beats were followed by ventricular complexes which, by comparison with the control tracings, were considered as examples of left posterior hemiblock. Details of their morphology have been reported previously (Kulbertus, 1972).

It is worth noting that the frontal maximal vector, if it consistently showed a slight inferior and rightward axis shift, was located only once further than +90°. The portion of QRS located to the right of the Y axis was greater than 25 per cent in 3 cases, and equal to 50 per cent in the remaining 4 cases.

The horizontal maximal vector was also slightly deviated posteriorly and to the right, but was located further than −90° in only 3 cases. The portion of the horizontal loop inscribed to the right of the Z axis did not exceed 25 to 30 per cent.

Left bundle-branch block (complete or incomplete)

A pattern of complete left bundle-branch block was obtained in 9 patients. Six others developed aberrantly conducted beats characterized, in the horizontal plane, by a centrifugal limb running backward in a clockwise fashion. Considered in isolation, such complexes might probably have been taken for cases of anterior infarction; however, in the present experimental procedure, the most probable diagnosis was that of incomplete left bundle-branch block (Chou *et al.*, 1974: Fig. 2, col. 8). Three patients in this group had a posterodiaphragmatic infarction. It is worth noting that the evidence for necrosis nearly disappeared in those subjects, when the pattern of incomplete left bundle-branch block developed.

Right bundle-branch block and its associations with left anterior and posterior hemiblock

Isolated right bundle-branch block was the most common conduction disturbance observed after atrial premature stimulation (19 cases). On the whole, the horizontal plane loop was more frequently rotated clockwise than counterclockwise, especially in subjects with normal control electrocardiograms. In 2 patients, both right bundle-branch block patterns could be obtained during the same experiment.

Combined right bundle-branch block and left anterior hemiblock were induced in 17 cases. This association represented the second most frequent

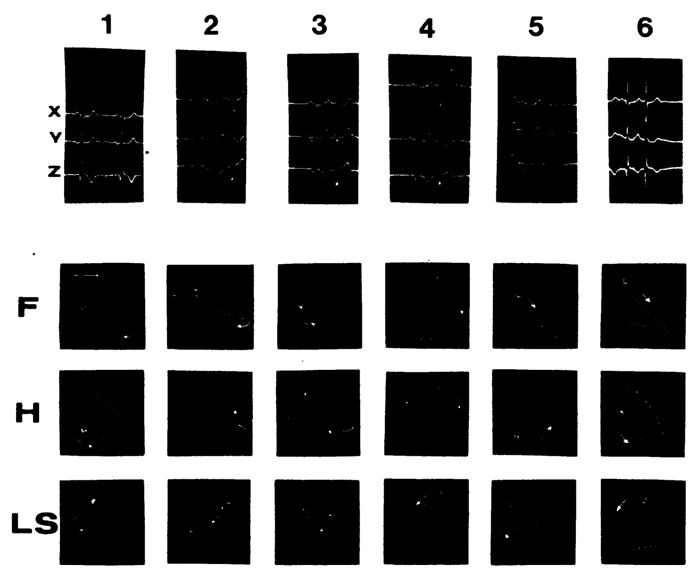

FIG. 3 *Tracings obtained from man aged 60 with peripheral vascular disease and normal resting electrocardiogram. 1: control tracing; 2: isolated right bundle-branch block; 3: left anterior hemiblock with right bundle-branch block; 4: left posterior hemiblock with right bundle-branch block; 5: slight modifications of QRS well displayed in horizontal plane, with leftward shift of the initial forces and attraction of both efferent and afferent limbs towards left posterior quadrant (slight degree of incomplete left bundle-branch block ?); 6: anterior displacement of initial and early forces of QRS with some signs suggesting tendency towards left posterior hemiblock. Loops are interrupted every 1·25 ms. Calibration: 0·5 mV.*

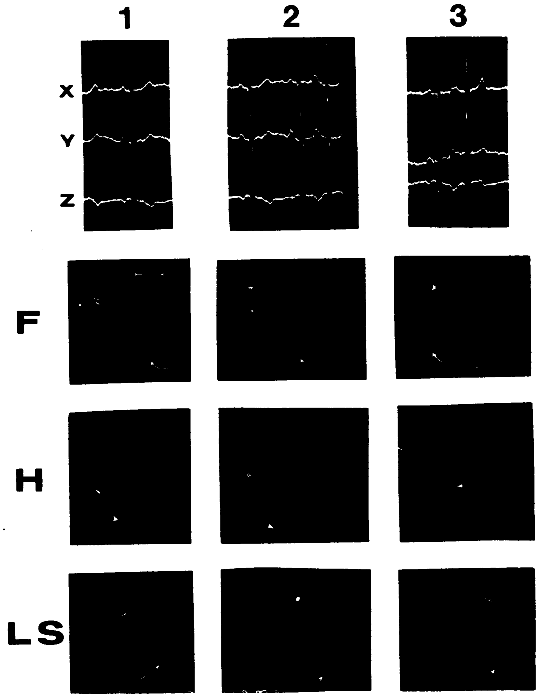

FIG. 4 *Tracings obtained from man aged 56, with history of previous myocardial infarction. Control tracing (1) is moderately abnormal and shows anterior displacement of horizontal maximal QRS vector with slightly prolonged anterior forces. Time required to reach maximum anterior voltage also exceeds normal values (>30 ms). These features are in keeping with old posterior lesion. In (2) and (3), aberrant conduction results in further increase of anterior forces. Concomitantly, initial vectors are displaced to left and frontal loop takes clockwise rotation instead of figure-of-eight which was present in control. Loops are interrupted every 1·25 ms. Calibration: 0·5 mV.*

pattern. The vectorcardiogram showed a type A morphology in 9 patients and a type B in 11. In 3 subjects, both morphologies were obtained during the same experiment. Finally, combined left posterior hemiblock and right bundle-branch block were induced in 11 patients (6 with the type A, and 5 with the type B).

Unclassified patterns

Twelve configurations of aberrant conduction could not be classified into the usual categories of intraventricular blocks. In 7, the alterations only consisted of a trivial modification of the QRS contour. In the remaining 5, the changes in QRS were much more conspicuous and rather unexpected. They consisted of a very significant anterior shift of the initial and early forces (Fig. 3). Three of these patients had a normal control vectorcardiogram; they developed aberrantly conducted beats in which the portion of the QRS area located anterior to the X axis exceeded 75 per cent and the duration of the anterior forces was much prolonged. The horizontal plane loop remained inscribed in a counterclockwise fashion. A similar, though less obvious anterior displacement of the initial forces took place in two further cases; one had a documented true posterior necrosis (Fig. 4), the other an anterior infarct. The electrical evidence of infarction was enhanced in the first instance and reduced in the second.

Conduction disturbance and myocardial infarction

In the group of 11 patients with documented myocardial infarction, 31 different aberrantly conducted complexes were recorded. On 3 occasions, the induced intraventricular conduction disturbance obscured the evidence of the pre-existing necrosis (2 instances of inferior wall infarction hidden by a left anterior hemiblock or left bundle-branch block; 1 instance of anteroseptal infarction hidden by a right bundle-branch block producing a clockwise and anteriorly displaced transverse plane loop). In all the other cases, by using previously proposed criteria (Kulbertus *et al.*, 1971; Benchimol and Desser, 1972; Chou *et al.*, 1974), the diagnosis of myocardial infarction could still be made, in spite of the intraventricular aberrant conduction.

It should be stressed that the posterior shift of initial forces seen in incomplete left bundle-branch block might lead to an erroneous diagnosis of anterior necrosis, whereas the anterior displacement described in the preceding paragraph could mimic a true posterior myocardial infarction.

Discussion

Recovery of excitability does not occur simultaneously in all the peripheral portions of the specialized intraventricular conduction system (Hoffman *et al.*, 1963, Van Dam, Hoffman, and Stuckey, 1964; Moe, Mendez, and Han, 1965). This feature accounts for the fact that, following atrial premature beats, impulse propagation may be altered because of a refractory state in parts of the usual conduction pathways. This results in aberrant ventricular conduction with morphological alterations of the QRS complex.

Recent studies have indicated that block frequently occurs at the level of the His bundle or bundle-branches, though it may also take place in the more distal portions of the intraventricular conducting system (Myerburg *et al.*, 1975a; Zipes *et al.*, 1975, Elizari, Greenspan, and Fisch, 1975). The degree of prematurity probably contributes to the determination of the site of block (Myerburg *et al.*, 1975b). One may reasonably expect that when the transmission delay involves only a limited number of peripheral Purkinje fibres, aberrant conduction will manifest itself by small variations of the QRS contour. Conversely, more extensive distal blocks as well as blocks in the proximal branches or subdivisions are likely to produce patterns of bundle-branch block, hemiblock, or bilateral conduction defect. In this study, as well as in others (Rosenbaum *et al.*, 1970), the commonest abnormality was right bundle-branch block, the next most frequently occurring anomaly being the association of right bundle-branch block with left anterior hemiblock. The reasons for this order of frequencies probably include differences in the length and in the duration of recovery time of each fascicle (Rosenbaum *et al.*, 1972).

Examples of aberrant conduction provide good material for studying the effects of any type of block on the human electrocardiogram or vectorcardiogram. Thus, some cases of aberrant conduction indicate that, even in its apparently chronic form, left anterior hemiblock may, after atrial premature stimulation, disappear or else be replaced by an isolated right bundle-branch block. The possible electrophysiological mechanisms that might explain such observations (supernormal phase of conduction; phase 4 block; discordance of conduction time and refractory periods) have been discussed by others (Rosenbaum *et al.*, 1972; Wu *et al.*, 1974).

As regards left posterior hemiblock, the present findings confirm that an abnormal rightward deviation of the maximal QRS frontal axis is not, as initially thought (Benchimol and Desser, 1971; Castellanos *et al.*, 1971), a prerequisite for the diagnosis of this type of partial left bundle-branch block. In fact, changes produced by left posterior hemiblock are often so small that the diagnosis can only be made by comparison with the control tracing (Strickland, Horan, and Flowers, 1972).

With right bundle-branch block, isolated or combined with partial left bundle-branch block, the present results corroborate, if still needed, the opinion that an anteriorly displaced, clockwise rotated horizontal plane loop is not, as stated in the past (Donoso *et al.*, 1955; Saltzman, Linn, and Pick, 1966), necessarily indicative of associated pathology, such as right ventricular hypertrophy or infarction of the posterior wall of the left ventricle, but may result from an abnormal pattern of cardiac excitation (Gardberg and Rosen, 1958; Scherlis and Lee, 1963; Penazola, Gamboa, and Sime, 1961; Cohen *et al.*, 1968; Kulbertus *et al.*, 1970a). It should be noted that, whereas in spontaneous right bundle-branch block, counterclockwise horizontal loops are more usually seen especially in individuals without obvious heart disease (Chou *et al.*, 1974; Witham, 1975), clockwise and anterior loops were found to be more frequent after atrial premature stimulation. The same observation was made by Cohen *et al.* (1968). No explanation has been suggested for this finding.

Finally, our data further illustrate that the presence of conduction disturbances, including hemiblocks (Rosenbaum *et al.*, 1970; Durrer, 1972), may modify in a dramatic fashion the electrocardiographic manifestations of myocardial infarcts and thus, sometimes, hamper their diagnosis. Concealment of an anteroseptal infarction by a type B right bundle-branch block deserves to be emphasized.

In addition to these mainly confirmatory data, the results reported in this paper point to a less well-known aspect of aberrant conduction. They indicate that the vectorcardiographic pattern characterized by an increase in amplitude and duration of the anterior forces can be the consequence of a conduction disturbance.

Prominent anterior forces are generally interpreted as being a result of right ventricular hypertrophy or posterior myocardial infarction. Many criteria, often deceptive, have been proposed to discriminate between those two conditions (Mathur and Levine, 1970; Kini and Pipberger, 1974), the differential diagnosis becoming important particularly in older patients who may have coronary artery disease, or pulmonary emphysema, or both.

In a study of 360 patients whose vectorcardiogram showed prolonged anterior forces, Mathur and Levine (1970) found 203 clear-cut instances of right ventricular hypertrophy and 85 of posterior wall myocardial infarction. There remained, however, 72 cases which failed to show any evidence for either diagnosis. Witham (1975) states, with some reservations, that such unusual anterior displacement of the QRS might represent a normal variant in the older age-group. Our results show that it may be related to a conduction disturbance. At the present stage of our knowledge, it seems impossible to specify where the conduction delay responsible for this vectorcardiographic abnormality actually takes place.

It has frequently been assumed that right bundle-branch block does not alter the first half of QRS. Boineau, Spach, and Ayers (1967) have, however, clearly showed that this opinion was erroneous.

At present, the fact that right bundle-branch block, alone or combined with a left divisional block, is not uncommonly associated with an anterior shift of the horizontal plane loop, is a well-known phenomenon. No proof has been provided to show that this anterior displacement is exclusively the result of the right-sided disturbance. None the less, there is a possibility that some kind of right bundle-branch conduction defect does account for the vectorcardiographic abnormality seen in the 5 cases under discussion.

On the other hand, one should also remember that the anatomy of the left bundle-branch seems more complicated than expected from the currently widely accepted bifascicular representation. Indeed, in addition to the anterior and posterior subdivisions, there is a considerable contingent of centroseptal fibres (Demoulin and Kulbertus, 1972), and all the peripheral subdivisions are interconnected by a very rich plexus of anastomoses. The interior network is thus very extensive (Lazzara, Yeh, and Samet, 1974; Myerburg *et al.*, 1975b), and it seems reasonable to suggest that, at times, anterior or posterior segments within this distal Purkinje network might be the site of delayed activation; this could also possibly result in shifts of the horizontal axis of QRS.

Further studies are surely needed to determine, on a firm basis, which part of the atrioventricular transmission system is involved in the conduction delay responsible for the prominent anterior forces observed in some of our cases.

The purpose of this discussion was merely to emphasize that, in addition to right ventricular hypertrophy and posterior infarction, conduction disturbances should be considered as a possible aetiology in the clinical interpretation of such tracings.

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