Classification of ventricular pre-excitation

Vectorcardiographic study

K. G. Lowe, D. Emslie-Smith, C. Ward, and Hamish Watson

*From the Department of Medicine, University of Dundee, Dundee;
and Royal Infirmary, Dundee*

In a study of 45 cases of ventricular pre-excitation, 19 were classified as type A and 20 as type B according to Rosenbaum's criteria, which depend on the polarity of the major deflections in the right praecordial leads and not, as is commonly thought, on the direction of the delta vector. Six cases that could not be classified as type A or type B were termed intermediate. Vectorcardiograms were recorded from 29, and these showed a wide but continuous range of values for both the delta and the main QRS vectors in all three planes. Any classification based on these features must, therefore, depend on arbitrary quantitative data.

Three patients in this series had associated right bundle-branch block. A review of the published reports on the association of pre-excitation and bundle-branch block failed to provide a rational basis for the classification of pre-excitation.

It is emphasized that Rosenbaum's classification is empirical and its validity is questioned.

The most widely accepted classification of ventricular pre-excitation is that proposed by Rosenbaum and his colleagues in 1945 into types A and B. It has proved useful in clinical practice but has been criticized or modified by numerous workers particularly those making vectorcardiographic studies (Bleifer *et al.*, 1959; Tranchesi *et al.*, 1959; Miller and Victorica, 1971) and epicardial and intracardiac recordings (Boineau and Moore, 1970; Wallace *et al.*, 1971). Rosenbaum's classification is based on the polarity of the major deflection in the right praecordial leads and not on the direction of the delta vector and this has been the cause of much confusion. Many authors classify their cases as A or B without adhering strictly to the criteria of Rosenbaum.

This confusion is unfortunate and is very evident at a time when our understanding of several aspects of pre-excitation is increasing rapidly. First, there are the anatomical studies, such as those of Lev, Sodi-Pallares, and Friedland (1963) and Lev (1966) which have demonstrated muscular connexions between atrium and ventricle (Kent bundle) or bypass fibres (James or Mahaim) closely related to the atrioventricular node and the bundle of His. Secondly, epicardial mapping of the spread of ventricular excitation, and cure, or attempted cure, by transection of the atrioventricular bypass at

thoracotomy, have been of value, particularly in type B pre-excitation associated with a Kent bundle at the right atrioventricular margin (Durrer and Roos, 1967; Burchell *et al.*, 1967; Cobb *et al.*, 1968; Wallace *et al.*, 1971). A third advance has come from the electrocardiographic recording of the bundle of His (Giraud *et al.*, 1960; Watson, Emslie-Smith, and Lowe, 1967; Scherlag *et al.*, 1969) coupled with atrial and ventricular pacing techniques (Massumi, Kistin, and Tawakkol, 1967; Durrer *et al.*, 1967; Castillo and Castellanos, 1970). This recent acceleration in the investigation of the fundamental aspects of pre-excitation has produced much circumstantial evidence that type B is usually right-sided and type A usually left-sided pre-excitation. For example, the surgical cure of type B pre-excitation by section at the right atrioventricular margin indicates that at least some type B cases are definitely associated with right ventricular pre-excitation.

On the other hand, Lister and his colleagues (1972) described a type B case where the site of earliest ventricular excitation was detected at the posterior base of the left ventricle, and activation thereafter spread slowly across the posterior base of both ventricles. Again, Boinéau and Moore (1970) described three types of pre-excitation A, B, and an intermediate one 'A-B', all of which they thought to be right-sided, whereas Touboul and his colleagues (1972) adduced electrophysiological

evidence that in type A pre-excitation the anomalous pathway lay preferentially on the left side of the heart. Recently Boineau and his colleagues (1973) recorded the sequence of epicardial activation in one case each of anterior right, posterior right, posterior left, and lateral left, ventricular pre-excitation. In these cases left and right ventricular pre-excitation corresponded to Rosenbaum's types A and B. This study suggests that we might yet have an accurate classification based on the precise location of all possible sites of pre-excitation, but a large number of correlations between surface scalar electrocardiograms and epicardial recordings will be required.

In view of the uncertainty and controversy arising from these studies some of which involve major surgery or invasive techniques of investigation which can only be applied to a minority of cases, the classification of pre-excitation is still in an unsatisfactory state. It is, therefore, important to keep under constant review classification based on routine non-invasive techniques, and we have reviewed a series of 45 cases with regard to the scalar and vectorcardiographic features.

Subjects

There were 45 cases of which 19 were classified type A and 20 type B according to the criteria of Rosenbaum *et al.* (1945). Differentiation was largely dependent on the QRS configuration in lead V₁. Six were classified as intermediate either because R and S were approximately equal or there were small polyphasic complexes in lead V₁ (Table 1 and Fig. 1). Three patients, all type B, had right bundle-branch block. In 1 patient, previously reported (Robertson *et al.*, 1963), right bundle-branch block and pre-excitation were both constantly present but in the other 2 they only occurred independently of each other, i.e. there was either pre-excitation without bundle-branch block or normal atrioventricular conduction with bundle-branch block. Twenty-one had clinical episodes of supraventricular tachycardia and 5 had paroxysmal atrial fibrillation. One patient, with mitral stenosis, had established atrial fibrillation. In 4 cases of paroxysmal atrial fibrillation and 2 cases of supraventricular tachycardia the QRS broadened to a bizarre pattern during the dysrhythmia, suggesting that anterograde conduction in the atrial reciprocating rhythm was by the anomalous route and retrograde conduction by the normal atrioventricular conducting tissue (Wellens, 1971). In 1 case of paroxysmal atrial fibrillation and all the other recordings of supraventricular tachycardia QRS narrowed during the dysrhythmia, showing the commoner circus rhythm, with anterograde conduction by the normal atrioventricular route and retrograde conduction by the anomalous route. This was the mechanism of tachycardia also in the patient with alternation between pre-excitation and right bundle-branch block, and the right bundle-branch block pattern persisted during the supraventricular tachycardia. Eight

patients had cardiac catheterization: 3 patients with a previous history of supraventricular tachycardia also had paroxysms during catheterization; of the 5 without a previous history of supraventricular tachycardia, 3 had paroxysms of supraventricular tachycardia during catheterization.

There were 4 cases of congenital heart disease, all of minor degree, 1 case of mitral stenosis, and 2 cases of myocardial infarction, clinically uneventful. A few had non-cardiac conditions (Table 1). The series, as a whole, could be regarded as being fairly healthy and free of severe heart disease. A minority of patients were moderately or severely handicapped, however, by recurrent tachydysrhythmia.

Methods

Vectorcardiograms were recorded from 29 cases (Table 2). The lead placement of Frank (1956) was used and recordings were made with a photographically recording Cambridge vectorcardiograph (No. C53811) or with a Sanborn vectorcardiograph. In the time-marked recordings, the light source was interrupted at intervals of 5 msec.

Results

There is a wide and continuous range of values for the delta and main QRS vectors in all three planes (Table 2, Fig. 2). The best correlation between the values of the delta and main QRS vectors is for those obtained in the horizontal plane (Table 3). In Table 2 cases have been arranged in order of increasing values for the delta vectors in the horizontal plane. This separates the type A and B cases with 3 intermediate cases approximately between the 2 groups. A broadly similar pattern would have emerged if the cases had been arranged in order of increasing values for the main QRS vectors in the horizontal plane. The other intermediate case (Case 21) is quite anomalous. This was the only case with a wide spatial angle (158°) between the delta and main QRS vectors in the horizontal plane (the mean spatial angle for the other 28 cases was 18° , with a range from 0° to 65°). Such a finding can only be explained by an unusual intraventricular conduction disturbance or serious unrelated cardiac pathology (Miller and Victorica, 1971). Case 21 was seriously handicapped by recurring bouts of tachycardia but no associated cardiac defect was suspected. However, his pre-excitation was intermittent and when atrioventricular conduction was normal he either had a normal scalar electrocardiographic pattern or right bundle-branch block with left axis deviation.

Discussion

In 1945 Rosenbaum *et al.* studied 10 cases of ventricular pre-excitation and classified them into 2

FIG. 1 Case 7. Ventricular pre-excitation of intermediate type. Note polyphasic complex in lead V_1 and the sinuous path of the delta wave in the horizontal plane.

groups, A and B, according to the scalar electrocardiographic appearances in leads V_1 , V_2 , and V_6 . In group A, R was the sole or largest deflection in these leads, and in group B, S or QS was the chief deflection in at least one of them. The frontal axis was in no way helpful in differentiating the cases. The authors pointed out that left axis deviation was common in ventricular pre-excitation and occurred in both types A and B. We have emphasized that

Rosenbaum's classification is not dependent on the polarity of the delta wave but paradoxically on the direction of the later electrical forces of ventricular depolarization. The authors stated that, 'the differences between these two types of cases are due, at least in part, to differences in the order of ventricular activation'. In group A the delta wave is positive and in group B either positive or negative in the right precordial leads.

TABLE I Clinical data of 45 cases of ventricular pre-excitation

Case No.	Age	Sex	Type	QRS configuration			Dysrhythmia
				V ₃ R	V ₁	V ₂	
1	52	M	B	rS	rS	RS	Supraventricular paroxysmal tachycardia
2	48	M	B	QS	rS	Rs	—
3	62	F	A	Rs	Rs	Rs	Supraventricular paroxysmal tachycardia
4	12	M	B	QS	rS	RS	Supraventricular paroxysmal tachycardia (during catheterization)
5	21	M	Intermediate	—	rsr'	R	—
6	31	F	A	rs	R	R	Supraventricular paroxysmal tachycardia
7	45	M	Intermediate	—	rsr's'r's"	RS	Supraventricular paroxysmal tachycardia
8	4	F	A	R	R	R	—
9	28	M	A	—	RS	RS	Supraventricular paroxysmal tachycardia
10	24	F	A	R	Rs	Rs	Supraventricular paroxysmal tachycardia (also during cardiac catheterization)
11	50	M	A	R	R	R	Supraventricular paroxysmal tachycardia
12	31	M	B	rS	rS	Rs	—
13	50	M	A	Rs	Rs	RS	Paroxysmal atrial fibrillation
14	18	F	A	—	Rs	Rs	Supraventricular paroxysmal tachycardia
15	9	M	A	—	Rs	Rs	Supraventricular paroxysmal tachycardia (during cardiac catheterization)
16	15	M	A	—	R	R	—
17	9/52	F	A	—	Rs	—	Supraventricular paroxysmal tachycardia
18	21	F	A	—	R	Rs	Supraventricular paroxysmal tachycardia
19	21	F	A	R	R	R	Supraventricular paroxysmal tachycardia
20	16	M	B	—	qrS	qRs	Supraventricular paroxysmal tachycardia (also during cardiac catheterization)
21	45	M	Intermediate	—	RS	RS	Supraventricular paroxysmal tachycardia
22	5	M	B	—	QS	R	Supraventricular paroxysmal tachycardia
23	40	F	B	—	rS	Rs	Paroxysmal atrial fibrillation
24	38	M	B	—	rS	rS	—
25	60	M	A	Rs	Rs	Rs	Supraventricular paroxysmal tachycardia
26	53	M	B	—	rS	rS	Supraventricular paroxysmal tachycardia
27	46	F	A	R	Rs	Rs	Supraventricular paroxysmal tachycardia
28	7	F	Intermediate	QR	qrsR'	R	Supraventricular paroxysmal tachycardia
29	5	M	B	—	rS	rS	—
30	38	F	B	—	rS	R	Paroxysmal atrial fibrillation
31	39	F	Intermediate	—	RS	R	—
32	59	M	Intermediate	rS	RS	Rs	Paroxysmal atrial fibrillation
33	13	F	B	—	QS	QS	—
34	39	M	B	QS	rS	R	—
35	63	M	A	Rs	Rs	Rs	—
36	63	F	B	—	QS	rsr'	—
37	28	M	B	QR	qrs	Rs	Paroxysmal atrial fibrillation
38	20	M	A	—	RS	RS	—
39	39	M	B	—	rS	rS	Supraventricular paroxysmal tachycardia
40	19	F	B	—	QS	Rs	—
41	49	M	B	—	rS	rS	—
42	4/12	F	A	Rs	Rs	Rs	Supraventricular paroxysmal tachycardia
43	12	M	B	QR	QRs	QRs	Supraventricular paroxysmal tachycardia (during cardiac catheterization)
44	16	M	A	—	Rs	Rs	Supraventricular paroxysmal tachycardia (also during cardiac catheterization)
45	34	F	B	—	QS	—	Established atrial fibrillation

Ueda *et al.* (1957) further subdivided Rosenbaum's group B into 2 types B and C dependent on the polarity of the delta wave in lead V₁ – positive in type B and negative in type C. In clinical practice this had little advantage and was not generally

adopted. Hejtmanick and Herrmann (1957) had difficulty in placing all their cases in either of Rosenbaum's categories and they designated a group as intermediate between A and B, a practice that we have followed.

Other features

Myocardial infarction, good recovery

Ebstein's anomaly

Epilepsy

Hypertension, asthma

Marfan's syndrome

Diabetes mellitus

Atrial septal defect

Acute glomerular nephritis, recovery

Intermittent right bundle-branch block + left axis deviation
during normal atrioventricular conduction

Right bundle-branch block alternating with pre-excitation

Ventricular septal defect, repaired surgically; cardiac
catheterization uneventful; right bundle-branch block
alternating with pre-excitation

Hypertension

Asthma, cardiac catheterization uneventful

Hypertension

Ebstein's anomaly, constant right bundle-branch block

Mitral stenosis

Since Rosenbaum published his classification, there has been an increasing interest in the direction of the delta vector in the right praecordial leads as the appropriate criterion for classification (Wallace *et al.*, 1971). Indeed, it has become com-

FIG. 2 Three-dimensional figure to illustrate the orientation of the delta vectors from 28 cases of ventricular pre-excitation.

mon practice to classify cases as A or B in this way and in disregard of Rosenbaum's criteria (Bleifer *et al.*, 1959; Tranchesi *et al.*, 1959). Grant, Tomlinson, and Van Buren (1958) even criticized Rosenbaum's classification on the grounds that the polarity of the delta wave in lead VI depended on trivial difference in the anteroposterior directions of the delta vectors, surely a misinterpretation of Rosenbaum's classification which depended on the polarity of the main QRS deflection and not of the delta wave.

Grant *et al.* (1958) also thought that the delta vector in the frontal plane was more important in classifying cases than that in the horizontal plane. They were able to show that in about half of the cases of intermittent pre-excitation the orientation of the delta vector determined the QRS frontal axis. This finding was confirmed and commented upon by Lowe *et al.* (1973). While this is an interesting phenomenon, and may or may not be dependent on pre-excitation involving either division of the left bundle-branch, it cannot serve as a basis for classification since it only applies in about half the cases of pre-excitation and, moreover, can only be studied in those cases in which pre-excitation is intermittent. It should be noted, however, that Grant, like Rosenbaum, was concerned as much with the main pathways of ventricular conduction as with the direction of the delta vector in seeking a logical classification of ventricular pre-excitation.

TABLE 2 *Delta and main QRS vectors in ventricular pre-excitation*

Case No.	Age	Sex	Type	Delta vector			Max. QRS vector			R/R + S in V _I (%)
				F	S	H	F	S	H	
36	63	F	B	+30	+160	-50	+34	+138	-32	0
33	13	F	B	-7	-167	-33	-63	-103	-18	0
22	5	M	B	+5	+160	-30	-16	-82	+5	5
45	34	F	B	-40	-80	-30	+9	+157	-27	0
40	19	F	B	+20	+110	-10	-10	-58	+14	0
24	38	M	B	+56	+92	-2	+38	+135	-26	0
37	28	M	B	-28	-87	-2	-92	-97	-2	20
4	12	M	B	+4	-*	0	-37	-93	+5	12
43	12	M	B (+RBBB)	-70	-89	0	+14	-82	+7	61
34	39	M	B	-50	-80	+4	-5	-85	+10	6
28	7	F	Intermediate	+32	-33	+8	+4	+26	+37	50
1	52	M	B	+34	+101	+10	-7	+152	-36	20
12	31	M	B	+20	+70	+20	+5	+6	+19	23
7	45	M	Intermediate	+35	+50	+30	+30	+48	+40	32
31	39	F	Intermediate	-10	-10	+42	+3	+7	+30	43
6	31	F	A	-30	-25	+46	+40	+48	+37	100
25	60	M	A	-67	-52	+48	-10	-24	+43	85
3	62	F	A	+20	+33	+51	+31	+19	+28	80
15	9	M	A	+70	+55	+55	+45	+20	+58	66
38	20	M	A	+55	+42	+60	+112	+47	+72	62
10	24	F	A	-30	-20	+68	+23	+10	+54	85
19	21	F	A	+85	+58	+68	+86	+43	+84	100
35	63	M	A	-70	-30	+70	-3	-20	+20	66
11	50	M	A	+55	+20	+74	+22	+24	+56	100
14	18	F	A	+80	+40	+80	+72	+45	+75	66
13	50	M	A	+60	+50	+85	+65	+90	+20	82
21	45	M	Intermediate	-*	-10	+100	+45	+140	-58	50
27	46	F	A	+82	+66	+108	+96	+49	+112	100
9	28	M	A	+125	+27	+110	+58	+38	+65	75

* Not measurable because vector at right angles to this plane.

It is very remarkable that Rosenbaum's classification, apparently empirical as it was and misused as it has been at times, has stood the test of time by proving useful in clinical practice, and provoking further thought about the fundamental mechanism of pre-excitation. It is particularly interesting that evidence has accumulated over the years suggesting that types A and B might correspond to left and right ventricular pre-excitation, respectively.

TABLE 3 *Correlation between delta and main QRS vectors in ventricular pre-excitation*

	Difference between delta and main QRS vectors (degrees)		
	Frontal mean (range)	Sagittal mean (range)	Horizontal mean (range)
Type A cases	36.0 (1-70)	22.1 (4-73)	20.7 (3-65)
Type B cases	39.0 (4-84)	61.4 (5-168)	15.3 (0-46)
'Intermediate' cases	15.3 (5-28)	57.0 (2-150)	52.3 (10-158)
All cases	35.1 (1-84)	42.5 (2-168)	22.8 (0-158)

Rosenbaum *et al.* (1945) and also later authors (Ueda *et al.*, 1957) used surface thoracic leads and oesophageal leads to study pre-excitation. A new approach was made by Sodi-Pallares and his colleagues (1948) when they used intracardiac electrocardiography to identify pre-excitation sites by registering the earliest negative deflections in the right ventricular cavity. They found 2 different intracardiac electrocardiographic patterns in a study of 5 cases which they termed group A and group B. Their findings were criticized on technical grounds by Grishman, Kroop, and Steinberg (1950) who also explored the right side of the heart with catheter electrodes and reported different patterns which led them to repudiate the classification of Rosenbaum.

With advances in cardiac catheterization techniques more extensive exploration of all 4 chambers of the heart became possible. Following the reports of several groups of workers (Hecht and Ritzmann, 1950; Coelho *et al.*, 1951; Hecht, 1957; Ueda *et al.*, 1957; Latour and Puech, 1957; Watson and Lowe, 1967), it became evident that Rosenbaum's types A and B were associated with intracardiac electrocardiographic patterns suggesting right and left

ventricular pre-excitation, respectively. As Grant and his colleagues (1958) pointed out, however, intracardiac electrocardiography as practised then was a relatively inexact way of plotting pathways of ventricular conduction and the published reports of its use in cases of pre-excitation were inconclusive.

Association of ventricular pre-excitation and bundle-branch block and its bearing on classification

A new approach was made by Gamboa *et al.* (1962) when they manipulated a cardiac catheter in the right ventricle so as to injure the right bundle-branch temporarily and produce transient right bundle-branch block. In patients with type A pre-excitation they were able by this manoeuvre to produce combined type A pre-excitation and right bundle-branch. By contrast, in a patient with intermittent type B pre-excitation they could only produce right bundle-branch block in the normally conducted beats and not in those showing pre-excitation. This led them to postulate that type B pre-excitation is a right ventricular phenomenon and that premature depolarization of much of the right ventricle by the anomalous conducting pathway precludes associated right bundle-branch block. This experimental work, along with the suggestive evidence gained from intracardiac electrocardiography, appeared to suggest that Rosenbaum's classification might have even more validity than perhaps had at first been envisaged by its authors.

Alternation between type B pre-excitation and right bundle-branch block had already been described in patients with Ebstein's anomaly by Kezdi and Wennemark (1958) and Cabrera, Feldman, and Olinto (1959). Other examples of this association in Ebstein's anomaly have subsequently been reported by Schiebler *et al.* (1959) and Miller and Victorica (1971). As Ebstein's anomaly is a right-sided cardiac lesion and is often associated with type B pre-excitation, the evidence seemed increasingly in favour of type B being right-sided pre-excitation. Alternation between type B pre-excitation and right bundle-branch block has been reported in patients without Ebstein's anomaly by Wolff (1959), Lombardi and Masini (1961), Schamroth and Krikler (1967), Gersony and Ekery (1969), Richmond and Pordy (1969), and Narula (1973), and we had 2 examples in this series of cases. This is much the commonest type of association between pre-excitation and bundle-branch block and it has received much comment in the reports on pre-excitation.

If type A is left-sided pre-excitation then alternation between type A and left bundle-branch block might be expected to occur in clinical practice. It

appears, however, to be rare. A case was recorded by Scherf and Bornemann (1969) but it was complicated by variation in the form of the P wave preceding the 2 types of QRS complex, a phenomenon well described by Scherf and James (1966). Case 3 in the paper by Pick and Fisch (1958) also appears to be an example of this alternation between type A and left bundle-branch block.

Assuming that types A and B pre-excitation are left and right-sided, respectively, it should be expected that clinical reports of pre-excitation with contralateral bundle-branch block would be forthcoming. In addition to Gamboa's experimental demonstration of the association of type A and right bundle-branch block, clinical reports of the association have been made by Pick and Fisch (1958), Castellanos, Mayer, and Lemberg (1962), Massumi (1970), and Schamroth and Lapinsky (1972). The association of type B and left bundle-branch block was reported by Pick and Fisch (1958), Burch and DePasquale (1961), Follath and Hallidie-Smith (1972), and Castillo *et al.* (1973).

Unfortunately, there is also contradictory evidence provided by the apparently paradoxical alternation between pre-excitation and contralateral bundle-branch block and the paradoxical coexistence of pre-excitation and ipsilateral bundle-branch block. Bauer (1957), Gonzalez-Abreu (1958), and Bleifer *et al.* (1959) reported cases of type B pre-excitation alternating with left bundle-branch block, and this is difficult to fit in with Gamboa's experimental work. Neutze, Kerr, and Whitlock (1973) reported a case of type A pre-excitation alternating with partial right bundle-branch block. The coexistence of type B pre-excitation and right bundle-branch block has been reported by Robertson *et al.* (1963), Zakopoulos, Tsatas, and Liokis (1964), Fernandez Caamano, Heller, and Lenègre (1967), and Chia (1973). Coexistent type A and left bundle-branch block has been described by Castellanos *et al.* (1962) and Varriale, Alfenito, and Kennedy (1966). These associations can be explained by supposing that only a small portion of a ventricle is pre-excited before normal atrioventricular conduction occurs and discloses a bundle-branch block pattern caused by an associated cardiac lesion. Alternatively it could indicate a gross pathological change in the affected ventricle, as might be the case in those patients with Ebstein's anomaly, type B pre-excitation, and coexistent right bundle-branch block (Robertson *et al.*, 1963).

When pre-excitation and bundle-branch block alternate the presence of a bundle-branch block pattern during supraventricular paroxysmal tachycardia will depend on the anterograde route of atrioventricular conduction. If this is by the normal

atrioventricular pathway then the bundle-branch block is present. If anterograde conduction is by the anomalous route, QRS is broad and bizarre and the record should not be confused with that of supra-ventricular tachycardia plus bundle-branch block or with ventricular tachycardia.

When the 'concertina effect' (Öhnell, 1944) occurs in patients with alternation between pre-excitation and bundle-branch block an interesting phenomenon is seen. In the absence of pre-excitation there is full-blown bundle-branch block but as the delta wave begins to appear and increase in degree so the bundle-branch block lessens and eventually disappears. This phenomenon has been well illustrated with type B pre-excitation and right bundle-branch block by Cabrera *et al.* (1959) and by Narula (1973).

In view of the contradictory evidence regarding bundle-branch block and pre-excitation, the most that can be argued is that some cases of type B pre-excitation affect the right ventricle and some of the type A cases affect the left ventricle.

Vectorcardiography

There have been several reports of vectorcardiographic studies of ventricular pre-excitation (Donzelot, Milovanovich, and Plavsic, 1949; Duchosal and Sulzer, 1949; Grishman and Jaffe, 1951; Cernohorsky, 1956; Friedberg, 1956; Odier, Montouchet, and Duchosal, 1957; Bleifer *et al.*, 1959; Tranchesi *et al.*, 1959; Portillo, 1971; Miller and Victorica, 1971). Bleifer, after excluding 5 'miscellaneous' cases in a series of 38, was able to differentiate two patterns of vectorcardiogram that correspond to the scalar electrocardiography patterns of types A and B pre-excitation classified according to Rosenbaum's criteria. In group A the delta vector and 'delta plus QRS' vector were oriented anteriorly in the horizontal plane between $+30^\circ$ and $+120^\circ$, whereas in group B the corresponding vectors were oriented to the left between -60° and $+30^\circ$. Tranchesi differentiated two groups depending on the polarity of the delta wave in lead V₂. In his type 1 pre-excitation (which comprised the majority of cases) delta was positive in lead V₂ and the delta vector lay between $+10^\circ$ and $+160^\circ$ in the horizontal plane; in type 2, delta was negative in lead V₂ and the delta vector lay between -5° and -20° in the horizontal plane.

In these 2 series as in ours, there is a wide and continuous spectrum of orientation of the delta vector in the horizontal plane, from -60° to $+120^\circ$ in Bleifer's series, -20° to $+160^\circ$ in Tranchesi's, and -50° to $+110^\circ$ in ours. Likewise the horizontal main QRS vectors ranged between -60° and

$+120^\circ$ in Bleifer's series, between -70° and $+120^\circ$ in Tranchesi's, and between -36° and $+112^\circ$ in ours. In none of these series did either the delta or main QRS vectors cluster into two sharply defined groups.

In all three series there was a better correlation between the delta vectors and the mean or maximal QRS vectors in the horizontal plane than in the other two planes. One reason for the poor correlation in the frontal and sagittal planes may be that about half of the cases show a striking shift in frontal axis, either to left or right when normal atrio-ventricular conduction gives way to pre-excitation in patients with intermittent pre-excitation (Grant *et al.*, 1958; Lowe *et al.*, 1973). This change in axis, based perhaps on pre-excitation spreading into one or other of the two main fascicles of the left bundle, may vitiate what otherwise might be a good correlation between delta and main QRS vectors in the frontal and sagittal planes.

Problems arise in classifying cases of pre-excitation when there is associated serious heart disease. Miller and Victorica (1971) studied a group of children of whom a high percentage had serious congenital heart disease with either left or right ventricular hypertrophy. They found it necessary to classify their cases as 'type A or B according to the anterior or posterior orientation, respectively, of the delta vector'. The delta and QRS vectors were widely divergent in the cases of serious heart disease except in Ebstein's anomaly. Tranchesi *et al.* (1959) had observed a similar divergence in patients with type A pre-excitation and left ventricular hypertrophy. In such cases classification is difficult with Rosenbaum's criteria, and it might be enough to leave them unclassified but indicate the vectorial orientation of the delta and main QRS forces.

Vectorcardiography is useful in diagnosis when pre-excitation and bundle-branch block are present simultaneously or where the pre-excitation complex simulates bundle-branch block. If one ventricle is partially depolarized before the other then there will be a corresponding later imbalance of electrical forces. Bleifer *et al.* (1959) commented on the altered initial and late forces of the QRS spatial loop when normal atrioventricular conduction is replaced by pre-excitation. 'The orientation of the QRS sE loops during WPW conduction in all planes appears so different from the normal, that it is hard to conceive that the dissimilarity is due to the addition of a delta vector to the normal vector. Not only the initial but also the terminal portion of the QRS sE loop is changed during WPW conduction.' These authors felt that early excitation was not just limited to one ventricle and that the entire conduction through both ventricles was abnormal. The late

QRS changes look not unlike partial or complete bundle-branch block of the contralateral ventricle, and indeed, it has long been known that type A pre-excitation simulates right bundle-branch block and type B simulates left bundle-branch block (Hejtmancik and Herrmann, 1957). There is a variation in the extent to which pre-excitation and conduction along the normal atrioventricular pathways contribute to the form of QRS not only between different patients but also in the same patient at different times, as in the 'concertina effect' (Öhnell, 1944). This latter effect can be induced by atrial pacing at increasing rates in patients with pre-excitation (Castellanos *et al.*, 1970). As the delta vector component of QRS increases in duration, it eventually gives rise to a broad bizarre QRS not unlike bundle-branch block showing that the whole of ventricular conduction has come from the pre-excitation focus. When this stage is reached His bundle recording shows that normal atrioventricular conduction has ceased. Portillo (1971) made a vectorcardiographic study of the concertina effect in pre-excitation. With an increasing degree of pre-excitation the vectorcardiogram superficially resembled an increasing degree of bundle-branch block (right bundle-branch block in type A and left bundle-branch block in type B). However, with advanced degrees of pre-excitation there was pronounced delay of the initial portion of the QRS loop but the late delay characteristic of bundle-branch block was absent. When pre-excitation and bundle-branch block actually coexist there is pronounced delay of both initial and late portions of the QRS loop (Robertson *et al.*, 1963).

Present status of classification

Rosenbaum's classification, in the original or modified forms, has proved useful as workers have groped towards a rational classification based on accurate anatomical location of the pre-excitation pathways. However, we have shown a wide continuous spectrum of both delta and main QRS vectors, and this must mean that anomalous atrioventricular conduction can occur at many different sites. There might be myocardial continuity anywhere along the left or right atrioventricular junctions (Kent bundles) or there might be many possible aberrations of the specialized atrioventricular conducting tissue. Any classification based on scalar or vector electrocardiography is at present completely arbitrary. For example, a vectorcardiographic classification could be made by choosing 0° in the horizontal plane for the delta or main QRS vectors as the dividing line between 2 types which would correspond roughly with Rosenbaum's types A and B. When there is a

continuum of values there must always be doubt about the dividing line and uncertainty about typing cases with values close to the dividing line. Moreover, cases with serious associated cardiac pathology or bundle-branch block are difficult to classify.

The arrival of new techniques such as epicardial electrocardiographic mapping has brought a new precision to locating pre-excitation pathways in selected cases, and as more such cases are reported and correlated with their electrocardiograms and vectorcardiograms, the basis will be laid for a rational classification. Until that is possible the need to continue with existing classifications is questionable. In the meantime it should be enough in individual cases to describe the electrocardiogram and vectorcardiogram with particular reference to the delta wave or vector and the subsequent pathways of ventricular excitation.

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Requests for reprints to Dr. Hamish Watson, Postgraduate Division, Faculty of Medicine, University of Dundee, Dundee DD1 4HN.