Value of the resting 12 lead electrocardiogram and vectorcardiogram for locating the accessory pathway in patients with the Wolff-Parkinson-White syndrome

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SUMMARY The resting 12 lead electrocardiogram and vectorcardiogram were reviewed in 47 patients with the Wolff-Parkinson-White syndrome (a) who had pre-excitation on the resting 12 lead electrocardiogram, (b) who had a single anterograde conducting accessory pathway assessed and located during preoperative electrophysiological study and during epicardial mapping at operation, and (c) in whom surgical division of the accessory pathway resulted in loss of pre-excitation. The site of the accessory pathway established during operation was compared with that established by evaluating the polarity of the delta wave and QRS complex on the resting 12 lead electrocardiogram. The electrocardiogram was assessed by the Rosenbaum criteria (Wolff-Parkinson-White type A, left-sided pathway; or type B, right-sided pathway), the Gallagher criteria (atrial pacing resulting in maximal pre-excitation), and the World Health Organisation criteria (a composite of previous studies). The Gallagher and World Health Organisation criteria were derived from patients demonstrating maximal pre-excitation that often required atrial pacing. The present study was designed to determine whether these criteria could be accurately applied to the resting 12 lead electrocardiogram on which the degree of pre-excitation was variable. The Rosenbaum criteria correctly identified a left sided accessory pathway in 26 of 34 patients and a right-sided accessory pathway in nine of 13 patients. The Gallagher and World Health Organisation criteria correctly identified the location in only 15 (32%) of the 47 patients. The resting vectorcardiogram was inaccurate for locating the accessory pathway.

Although published criteria are useful for identifying the site of the accessory pathway from an electrocardiogram obtained when rapid atrial pacing is being used to achieve maximal pre-excitation, they are not suitable for identifying the exact site of an accessory pathway from the resting 12 lead electrocardiogram.

The electrocardiogram from patients with the Wolff-Parkinson-White syndrome¹⁻³ classically demonstrates a short PR interval, a broad QRS complex, and typical slurring of the initial portion of the

QRS complex, referred to as a delta wave.⁴ The PR interval and the width of the QRS complex, or degree of pre-excitation, may vary^{2,3} depending on the location of the accessory pathway; the intra-atrial, atrioventricular node, His-Purkinje, and accessory pathway conduction times; autonomic tone; and cardioactive medications.^{2,3,5} These factors may result in a spectrum of findings, including no apparent pre-excitation, varying degrees of

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pre-excitation, or maximal pre-excitation, on the resting 12 lead electrocardiogram in patients with the Wolff-Parkinson-White syndrome.

Before electrophysiological testing, knowledge of the location of an accessory pathway is useful because it may be important initial evidence of multiple accessory pathways, especially in patients who have one pathway that conducts only in the anterograde direction and accounts for the delta wave and a second pathway that conducts only in the retrograde direction and participates in reentrant tachycardia (concealed accessory pathway).⁶ Criteria for locating the accessory pathway from the 12 lead electrocardiogram have been published.¹⁻³ These criteria^{2,3} were derived from electrocardiograms demonstrating maximal pre-excitation. This often requires rapid atrial pacing. The use of such criteria to determine accurately the location of the accessory pathway from the resting electrocardiogram has not previously been assessed and forms the basis for this study.

Patients and methods

PATIENTS

Between 1976 and 1985, 47 patients (32 male and 15 female) with the Wolff-Parkinson-White syndrome met the following criteria for entry into this study: (a) presence of a delta wave on the resting 12 lead electrocardiogram; (b) presence of a single anterograde conducting accessory pathway found at preoperative electrophysiological study and confirmed by epicardial mapping during operation; and (c) loss of pre-excitation after surgical division of the accessory pathway. The mean age of the patients was 28 years (range 7-65 years). Eight patients had associated cardiac disorders: dilated cardiomyopathy and left lateral accessory pathway in one, atrial septal defect and left paraseptal accessory pathway in one, and Ebstein's anomaly with a right-sided accessory pathway in six. Four patients had hypertension.

ELECTROCARDIOGRAM

The resting 12 lead electrocardiogram was recorded at 25 mm/s and a gain of 10 mm/mV. All patients were in sinus rhythm, and the mean heart rate was 71 beats/min (range 47-113 beats/min). If multiple electrocardiograms were obtained from a patient, the one demonstrating the most pre-excitation was chosen for analysis. All recordings were analysed by two of us. The delta wave polarity was recorded as being positive, negative, or isoelectrical during the first 40 ms of the beginning of the QRS complex (positive, most or all of the initial slurring with a positive deflection; negative, most or all of the initial

slurring with a negative deflection; and isoelectrical, no slurring of the initial part of the QRS or an initial downward or upward deflection followed by a reversed deflection to the baseline during the first 40 ms of the QRS complex).

In 32 patients, three simultaneous channels of the electrocardiogram were recorded. These were grouped as follows: I, II, and III; aVR, aVL, and aVF; V1, V2, and V3; and V4, V5, and V6. In these patients the onset of the delta wave was determined as the time when the initial deflection was observed in one of the three simultaneously recorded leads. In the 15 remaining patients, the recordings were not simultaneous, and the delta wave was analysed independently in each lead.

VECTORCARDIOGRAM

The vectorcardiogram was obtained simultaneously with the 12 lead electrocardiogram in each patient. Computer analysis allowed for determination of the vector direction at 10, 20, 30, and 40 ms, with a mean vector at 30 ms (R30).

ELECTROPHYSIOLOGICAL EVALUATION AND EPICARDIAL MAPPING

Each patient had electrophysiological testing with methods that have previously been reported.^{7,8} Left-sided accessory pathways were located by means of recordings of left atrial and left ventricular electrograms from an electrode catheter placed in the coronary sinus, and right-sided accessory pathways were located by a mapping electrode catheter during ventricular pacing and reciprocating tachycardia.⁹ Epicardial mapping was performed at the time of operation⁸⁻¹⁰ in all patients. The ventricular epicardial activation sequences were recorded dur-

Fig 1 Schematic drawing at the level of the mitral and tricuspid valves, demonstrating epicardial locations during intraoperative electrophysiological mapping (C-G, L-P) to locate accessory atrioventricular pathway. (By permission of the Mayo Foundation.)

Table 1 World Health Organisation task force criteria for locating the accessory atrioventricular pathway by the resting 12 lead electrocardiogram

Condition statements

- (S1) Delta wave (initial QRS) positive in I
- (S2) Delta wave positive in V1
- (S3) Delta wave negative in V1
- (S4) Delta wave isoelectrical in V1
- (S5) Q or QS waves in I and V6
- (S6) Q or QS waves in III and aVF
- (S7) Main QRS positive in III
- (S8) Main QRS negative in III
- (S9) Main QRS positive in V1
- (S10) Main QRS negative in V1
- (S11) Delta wave positive in II and aVF and positive or isoelectrical in III
- (S12) Delta wave negative in II, III, aVF
- (S13) Delta wave positive from V2 until V6
- (S14) Delta wave negative or isoelectrical in V6
- (S15) QRS configuration rS in V1 and Rs in V2

Criterion for anterior right ventricular pre-excitation:

S1 and S4 and S8 and S10

Criterion for posterior right ventricular pre-excitation:

S3 and S6 and S8 and S10

Criterion for posterior left ventricular pre-excitation:

S1 and S2 and S6 and S8 and S9 and S14

Criterion for lateral left ventricular pre-excitation:

S2 and S5 and S7 and S14

Criterion for anterior paraseptal pre-excitation:

S1 and S4 and S11

Criterion for posterior paraseptal pre-excitation:

S1 and S12 and S13 and S15

From Willems *et al*³ by permission of the American College of Cardiology.

ing sinus rhythm and atrial pacing from a site close to the accessory pathway. Atrial activation was determined during ventricular pacing and reciprocating tachycardia in all patients. The site of the accessory pathway was classified as: left lateral, left posterior, posterior paraseptal/septal, right posterior, and right lateral (fig 1).

The surgical approach to division of the accessory pathway has been described elsewhere.^{8,10} In all patients division of the accessory pathway at the site corresponding to the earliest epicardial activation resulted in disappearance of pre-excitation. This was demonstrated by the surface electrocardiogram, the absence of pre-excitation during incremental atrial pacing, and the presence of type 1 second degree atrioventricular block during atrial pacing.

PUBLISHED CRITERIA FOR LOCATING THE ACCESSORY PATHWAY

In all patients the preoperative resting electrocardiogram was compared with the following criteria: (a) Rosenbaum criteria¹ (Wolff-Parkinson-White type A, in which there is a predominantly positive QRS complex in V1 and V2, and Wolff-Parkinson-White type B, in which there is a predominantly negative QRS complex in V1 and V2; (b) Gallagher criteria² (delta wave polarity, as recorded during rapid atrial

- 1 RIGHT ANTERIOR PARASEPTAL
- 2 RIGHT ANTERIOR
- 3 RIGHT LATERAL
- 4 RIGHT POSTERIOR
- 5 RIGHT PARASEPTAL
- 6 LEFT POSTERIOR PARASEPTAL
- 7 LEFT POSTERIOR
- 8 LEFT LATERAL
- 9 LEFT ANTERIOR
- 10 LEFT ANTERIOR PARASEPTAL

DELTA WAVE POLARITY

	I	II	III	AVR	AVL	AVF	V1	V2	V3	V4	V5	V6
①	+	+	+(*)	-	+(*)	+	+	+	+(*)	+	+	+
②	+	+	-(*)	-	+(*)	+(*)	+	+(*)	+(*)	+	+	+
③	+	+(*)	-	-	+	-(*)	+	+	+	+	+	+
④	+	-	-	-	+	-	+(*)	+	+	+	+	+
⑤	+	-	-	-(*)	+	-	+	+	+	+	+	+
⑥	+	-	-	+	-	-	+	+	+	+	+	+
⑦	+	-	-	+(*)	+	-	+	+	+	+	+	-(*)
⑧	-(*)	+	+	+(*)	-(*)	+	+	+	+	+	-(*)	-(*)
⑨	-(*)	+	+	-	-(*)	+	+	+	+	+	+	+
⑩	+	+	+(*)	-	+	+	+(*)	+	+	+	+	+

± = Initial 40 ms delta wave isoelectric

⊕ = Initial 40 ms delta wave positive

- = Initial 40 ms delta wave negative

Fig 2 Electrocardiographic classification of Wolff-Parkinson-White syndrome as defined by Gallagher *et al*.² Ten representative sites are depicted on a cross section of ventricles at level of atrioventricular rings. Expected polarity of delta waves resulting from pre-excitation at these sites is indicated for each of the 12 standard leads, based on analysis of mean initial forces (40 ms) of ventricular depolarisation. (From Gallagher *et al*.² By permission of Grune and Stratton.)

pacing resulting in maximal pre-excitation during the electrophysiological study (fig 2)); and (c) World Health Organisation criteria,³ which are a composite of previous criteria (table 1). We did not require complete concordance between all of the criteria for identification of the site of a pathway: with the Gal-

ble 2 Delta wave polarity on the resting 12 lead electrocardiogram in patients with left lateral or left posterior accessory pathways

Accessory pathway location	Patient	Lead*											Type of WPW† ¹	Concordance of criteria‡		
		I	II	III	R	L	F	V1	V2	V3	V4	V5		V6	Gallagher ²	WHO ³
Left lateral, QRS > 120 ms	1	+	±	±	±	±	±	+	+	+	+	+	±	A	Y	N
	2	±	+	+	±	±	+	+	+	+	+	+	±	A	N	Y
	3	+	—	—	—	—	—	+	+	+	+	+	±	A	N	N
	4	±	+	+	—	—	—	+	+	+	+	+	+	B	N	N
	5	±	+	+	—	±	+	+	+	+	+	+	+	A	N	N
	6	+	+	+	—	±	+	+	+	+	+	+	+	B	N	N
	7	+	±	±	—	±	±	+	+	+	+	±	±	A	Y	N
	8	—	+	+	±	—	+	+	+	+	+	+	±	A	N	Y
Left lateral, QRS < 120 ms	1	±	±	±	±	±	±	+	+	+	+	±	±	B	Y	N
	2	—	+	+	—	—	+	+	+	+	+	±	±	A	N	Y
	3	±	+	+	±	—	+	±	±	±	+	+	±	B	N	N
	4	±	+	+	±	—	+	+	+	+	+	+	±	A	N	Y
	5	±	+	+	±	—	+	+	+	±	+	+	+	B	N	N
	6	±	+	+	—	—	+	+	+	+	+	+	+	A	N	N
	7	—	±	±	±	±	±	+	+	+	+	±	—	A	Y	Y
	8	±	+	+	±	±	+	±	+	±	+	±	±	A	N	N
	9	+	+	+	—	±	+	+	+	±	+	±	+	A	N	N
	10	+	+	—	—	+	±	±	±	+	+	+	±	A	N	N
Left posterior, QRS > 120 ms	1	±	±	±	±	+	±	+	+	+	+	±	±	A	N	N
	2	±	+	+	—	±	+	+	+	+	+	+	+	A	N	N
	3	±	±	±	±	±	±	+	+	+	+	±	—	A	N	Y
	4	+	±	±	—	±	±	+	+	+	+	+	+	A	N	N
	5	+	±	—	—	+	±	+	+	+	+	+	+	A	N	Y
	6	+	+	—	—	+	±	±	+	+	+	+	+	A	N	N
	7	+	+	+	—	+	+	+	+	+	+	+	+	A	N	N
Left posterior, QRS < 120 ms	1	—	+	+	±	—	+	+	+	+	+	±	±	B	N	N
	2	±	+	+	—	±	+	+	+	+	+	+	+	A	N	N
	3	±	±	±	±	±	±	±	±	±	+	+	±	A	N	N
	4	—	+	+	±	—	+	+	+	+	+	±	±	A	N	N
	5	+	—	—	—	+	—	±	+	+	+	+	±	A	Y	N
	6	±	±	±	±	±	±	±	±	+	+	+	±	B	N	N

+, positive delta wave; —, negative delta wave; ±, isoelectric delta wave.

†PW, Wolff-Parkinson-White syndrome.

‡, no (criteria did not identify location of pathway); Y, yes (criteria did identify location of pathway).

ble 3 Usefulness of established criteria to locate the accessory pathway by the resting 12 lead electrocardiogram in patients with the Wolff-Parkinson-White syndrome

Accessory pathway location	No of patients	Rosenbaum criteria ¹ (type of WPW* and No of patients)	Gallagher criteria ²			World Health Organisation criteria ³		
			Location correctly identified (No of patients)	Best correlations†	Worst correlations‡	Location correctly identified (No of patients)	Best correlations†	Worst correlations‡
Left lateral	18	A, 13 B, 5	4	+V1 to V4 ±V6	±II, III, F −V6, ± −V5	5	+V1, ±V6 +QRS _{III}	Q-QS _I , V6 −V6
Left posterior	13	A, 11 B, 2	1	+V1 to V5	−II, III, F, +I, L −V6	2	+V1 +QRS _{V1}	−V6, +I −QRS _{III}
Right posterior/septal	9	Left A, 2 B, 1 Right A, 3 B, 3	2	Left +I, L, V1 to V5 −II, III, F	+V6, −R	2	−II, III, F +I	+V2 to V6 rS _{V1} , RS _{V2}
Right posterior	3	A, 1 B, 2	3	Right +I, L, V2 to V5 −II, III, F +I, L, V3 to V6 ±V1	±V1 ±V2	3	Q-QS _{III} , F	−V1
Right lateral	4	B, 4	2	−II, III, F, R +I, L, V4 to V6 −III, F, R	±(−) II ±V1 to V2	3	−QRS _{III} , V1 −QRS _{III} , V1 +I	±V1

+, positive delta wave;

—, negative delta wave;

±, isoelectric delta wave;

†PW, Wolff-Parkinson-White syndrome.

‡60% of electrocardiograms had these findings.

§40% of electrocardiograms had these findings.

Table 4 Vector direction at 10, 20, 30, and 40 ms on the resting vectorcardiogram in patients with left lateral or left posterior accessory pathways

Accessory pathway location	Patient	Frontal*					Sagittal†					Horizontal‡			
		10	20	30	R30§	40	10	20	30	R30§	40	10	20	30	R30§
Left lateral, QRS > 120 ms	1	L	R	R	R	L	S	I	I	I	I	A	A	A	A
	2	N	R	L	L	L	I	I	I	I	I	A	A	A	A
	3	L	L	L	L	L	I	S	S	S	S	A	A	A	A
	4	R	L	L	L	L	I	I	I	I	I	A	A	A	A
	5	L	L	R	L	R	NA	NA	NA	NA	NA	A	A	A	A
	6	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A
	7	L	L	L	L	L	I	I	I	I	I	A	A	A	A
	8	R	R	R	R	R	I	I	I	I	I	A	A	A	A
Left lateral, QRS < 120 ms	1	R	R	R	R	R	I	N	I	I	S	A	A	A	A
	2	R	L	L	L	L	I	S	S	S	I	A	A	A	A
	3	R	R	R	R	L	I	I	I	I	I	A	A	A	A
	4	L	L	L	L	R	I	I	I	I	I	A	A	A	A
	5	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A
	6	L	L	L	L	L	I	I	I	I	I	A	A	A	A
	7	L	R	R	R	R	NA	NA	NA	NA	NA	A	A	A	A
	8	L	L	L	L	R	NA	NA	NA	NA	NA	A	A	A	A
	9	L	L	L	L	L	I	I	I	I	I	A	A	A	A
	10	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A
Left posterior, QRS > 120 ms	1	N	L	L	L	L	I	I	N	I	S	A	A	A	A
	2	L	L	L	L	L	I	I	I	I	I	A	A	A	A
	3	R	R	R	R	R	I	I	S	N	S	A	A	A	A
	4	R	R	N	R	L	NA	NA	NA	NA	NA	A	A	A	A
	5	L	L	L	L	L	S	S	S	S	S	A	A	A	A
	6	L	L	L	L	L	I	I	I	I	I	A	A	A	A
	7	L	L	L	L	L	I	I	I	I	I	A	A	A	A
Left posterior, QRS < 120 ms	1	R	R	L	R	L	I	I	I	I	I	A	A	A	A
	2	L	L	L	L	L	I	I	I	I	I	A	A	A	A
	3	L	L	L	L	R	I	I	I	I	S	A	A	A	A
	4	L	L	R	R	L	NA	NA	NA	NA	NA	A	A	A	A
	5	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A
	6	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A

*L, left; R, right; N, neutral. †I, inferior; S, superior; NA, not available. ‡A, anterior. §R30, mean vector of first 30 ms.

Table 5 Delta wave polarity on the resting 12 lead electrocardiogram in patients with posterior paraseptal, right posterior, or right lateral accessory pathways

Accessory pathway location	Patient	Lead*											Type of WPW†	Concordance of criteria‡	
		I	II	III	R	L	F	V1	V2	V3	V4	V5		Gallagher²	Waxman³
Left posterior paraseptal, QRS > 120 ms	1	+	-	-	±	+	-	+	+	+	+	±	A	Y	
	2	+	-	-	±	±	-	-	-	-	+	+	B	N	
	3	+	-	-	±	+	-	+	+	+	+	+	A	Y	
Right posterior paraseptal, QRS > 120 ms	1	+	-	-	-	+	-	±	+	+	+	+	B	Y	
	2	+	±	±	-	+	±	+	+	+	+	+	A	N	
	3	+	-	-	±	+	-	+	+	+	±	±	B	N	
	4	+	-	-	±	+	-	+	+	+	+	+	A	Y	
	5	+	±	-	-	+	±	-	+	+	+	±	A	N	
	6	+	-	-	-	+	-	±	+	+	+	+	B	Y	
Right posterior, QRS > 120 ms	1	+	-	-	-	+	-	±	+	+	+	+	B	Y	
	2	+	±	-	-	+	-	±	+	+	+	+	A	Y	
Right posterior, QRS < 120 ms	1	+	-	-	-	+	-	+	+	+	+	+	B	Y	
Right lateral, QRS > 120 ms	1	+	+	-	-	+	-	+	+	+	+	+	B	N	
	2	+	+	+	-	±	+	-	±	±	+	+	B	N	
	3	+	-	-	±	±	-	±	+	+	+	+	B	Y	
Right lateral, QRS < 120 ms	1	+	+	-	-	+	-	+	+	±	+	+	B	Y	

*+, positive delta wave; -, negative delta wave; ±, isoelectric delta wave.

†WPW, Wolff-Parkinson-White syndrome.

‡N, no (criteria did not identify location of pathway); Y, yes (criteria did identify location of pathway).

Locating the accessory pathway

Table 6 Vector direction at 10, 20, 30, and 40 ms on the resting vectorcardiogram in patients with posterior paraseptal, right posterior, and left lateral accessory pathways

Accessory pathway location	Patient	Frontal					Sagittal					Horizontal				
		10	20	30	R30	40	10	20	30	R30	40	10	20	30	R30	40
Posterior paraseptal, RS > 120 ms	1	L	L	L	L	L	S	S	S	S	S	A	A	A	A	A
	2	R	L	L	L	L	I	I	I	I	S	P	P	P	P	P
	3	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A	A
Left posterior paraseptal, RS > 120 ms	1	L	L	L	L	L	I	I	S	S	S	A	A	A	A	A
	2	L	L	L	L	L	N	N	S	S	S	A	A	A	A	A
	3	R	L	L	L	L	S	S	S	S	S	A	A	P	A	P
	4	L	L	L	L	L	NA	NA	NA	NA	NA	A	A	P	A	A
	5	L	L	L	L	L	NA	NA	NA	NA	NA	P	P	P	P	P
	6	L	L	L	L	L	I	S	S	S	S	A	A	P	P	P
Left posterior, QRS > 120 ms	1	L	L	L	L	L	—	—	S	S	S	A	A	A	A	P
	2	L	L	L	L	L	NA	NA	NA	NA	NA	P	N	A	A	A
Left posterior, QRS < 120 ms	1	R	L	L	L	L	NA	NA	NA	NA	NA	A	A	A	A	A
Left lateral, QRS > 120 ms	1	R	R	L	R	L	N	S	S	S	S	A	A	A	A	A
	2	L	L	L	L	L	I	I	I	I	I	A	P	P	P	P
	3*															
Left lateral, QRS < 120 ms	1	L	L	L	L	L	S	S	S	S	S	A	P	A	A	A

* The vector was not obtained for this patient.

Left, L; Right, R; Inferior, I; Superior, S; NA, not available; N, neutral; A, anterior; P, posterior; R30, mean vector of first 30 ms.

latter criteria an accessory pathway location was correctly identified by the 12 lead electrocardiogram if the polarity of the delta wave in at least nine of the 12 leads conformed with the published criteria (fig 2); and for the World Health Organisation criteria³ an accessory pathway location was correctly identified by the 12 lead electrocardiogram if all of the criteria (table 1) except one were correct.

Results

LEFT LATERAL ACCESSORY PATHWAY

Type A Wolff-Parkinson-White syndrome was present in 13 of the 18 patients (table 2). The pathway location was correctly identified by the Gallagher criteria² in four of the patients and by the World Health Organisation criteria³ in five (table 3).

The vector for R30 (table 4) was anterior in all 18 patients, oriented to the left in 13 of the patients, and inferior in 10 of the 12 patients for whom such information was available.

LEFT POSTERIOR ACCESSORY PATHWAY

Type A Wolff-Parkinson-White syndrome was present in 11 of the 13 patients (table 2). The pathway location was correctly identified by the Gallagher criteria² in one patient and by the World Health Organisation criteria³ in two (table 3).

The vector for R30 (table 4) was anterior in all patients, oriented to the left in nine of the 13 patients, and inferior in seven of the nine patients for whom such information was available.

POSTERIOR PARASEPTAL ACCESSORY PATHWAY (TABLE 5)

Type A Wolff-Parkinson-White syndrome was present in two of the three patients with a left posterior paraseptal accessory pathway and three of the six with a right posterior paraseptal accessory pathway. The pathway location was correctly identified by the Gallagher criteria² in five of the nine patients and by the World Health Organisation criteria³ in two (table 3).

The vector for R30 (table 6) was anterior in six of the nine patients, oriented to the left in all nine patients, and superior in five of the six patients for whom such information was available.

RIGHT POSTERIOR ACCESSORY PATHWAY (TABLE 5)

Type B Wolff-Parkinson-White syndrome was present in two of the three patients. All three patients had the pathway location correctly identified by the Gallagher criteria² and the World Health Organisation criteria³ (table 3).

The vector for R30 (table 6) was anterior in all three patients, oriented to the left in all three patients, and superior in the one patient for whom such information was available.

RIGHT LATERAL ACCESSORY PATHWAY (TABLE 5)

Type B Wolff-Parkinson-White syndrome was present in all four patients. The pathway location was correctly identified by the Gallagher criteria² in

two of the four patients and by the World Health Organisation criteria³ in three (table 3).

The vector for R30 (table 6) was anterior in two of the patients, oriented to the left in two of the patients, and superior in two of the patients. A vector was not obtained in the fourth patient.

Discussion

The concept that pre-excitation in Wolff-Parkinson-White syndrome was the result of conduction over an accessory atrioventricular pathway remained speculative until 1967 when Durrer and Roos provided evidence for atrioventricular conduction over an accessory pathway by epicardial mapping of the heart.¹¹ Work by Burchell *et al*¹² and Boineau and Moore¹³ further substantiated this belief, and in 1968, Cobb *et al*¹⁴ and Sealy *et al*¹⁵ were the first to divide an accessory pathway successfully. Because the Wolff-Parkinson-White syndrome can be cured by surgical ablation the ability to locate the site of pre-excitation has become of great importance.

Electrocardiography and vectorcardiography¹⁶⁻¹⁸ have remained the two most widely used methods to predict the location of the accessory pathway. Recently, echocardiography,¹⁹ body surface mapping,^{20,21} phase imaging,²² and the moving dipole²³ have also been used in an attempt to locate the site of an accessory pathway.

TYPE A AND TYPE B WOLFF-PARKINSON-WHITE SYNDROME

The classification by Rosenbaum *et al*¹ of Wolff-Parkinson-White syndrome into type A or type B has stood the test of time because of its simplicity. Type A was believed to be due to left posterobasal pre-excitation, and type B to right lateral pre-excitation.²⁴ The Rosenbaum criteria correctly identified a left-sided accessory pathway in 76% of our patients and a right-sided accessory pathway in 69% of our patients. This classification, however, does not help to separate free wall and paraseptal/septal locations.

VECTORCARDIOGRAPHY IN WOLFF-PARKINSON-WHITE SYNDROME

Vectorcardiography has also been used to locate the accessory pathway. In this study it did not accurately identify the location of the accessory pathway because (a) the vector was anterior in most (89%) of the patients; (b) the vector was to the left in 71% of the patients with a left free wall accessory pathway, in all patients with a posterior paraseptal accessory pathway, and in 83% of the patients with a right posterior or right lateral accessory pathway; and (c)

the vector was inferior in 81% of the patients with a left free wall accessory pathway, superior in 83% of the patients with a posterior paraseptal accessory pathway, and superior in 75% of the patients with a right free wall accessory pathway.

These findings do not support a previous study that suggested a vector directed anteriorly and to the right indicated a left lateral accessory pathway and a vector directed to the left and anteriorly indicated a paraseptal accessory pathway.²⁵ The suggestion in another study that a left lateral accessory pathway had a 10 ms vector directed inferiorly and a 20 ms vector directed to the right²⁶ was not confirmed by our study.

ELECTROCARDIOGRAPHY AND EPICARDIAL MAPPING CORRELATIONS

Epicardial mapping during operation provides an opportunity for a comparison with the results of the non-invasive determination of accessory pathway location. Boineau *et al*, Frank, and Gallagher *et al*, using 12 lead electrocardiography,^{5,27,28} and Tonkin *et al*, using vectorcardiography,²⁶ provided the first correlations. However, criteria for locating the accessory pathway from the 12 lead electrocardiogram based on the delta wave polarity were not adopted until the important article by Gallagher *et al*.² Their review provided information relating the delta wave polarity in the 12 standard leads obtained during rapid atrial pacing (resulting in maximal pre-excitation) to the accessory pathway location determined by epicardial mapping during operation for 10 different accessory pathway locations. They suggested that their results should be applied to patients in whom the QRS complexes were more than 140 ms.

Recently, the World Health Organisation³ developed a classification of accessory pathway location according to the 12 lead electrocardiogram from a composite of previous studies^{1,2,5,29} and suggested six sets of criteria for accessory pathway location. Because of fusion caused by conduction over the atrioventricular node and the accessory pathway, they found that pre-excitation and the width of the QRS complex may vary but they did not strictly limit the classification to a certain QRS width. From a practical standpoint, patients with the Wolff-Parkinson-White syndrome who clearly have pre-excitation on the resting 12 lead electrocardiogram often have a QRS width of less than 120 ms. In our series, 18 of the 47 patients had a QRS width of less than 120 ms and only 10 had a QRS of 140 ms or more.

The previously reported criteria^{2,3} were developed and are useful for identifying the accessory pathway location from an electrocardiogram

Locating the accessory pathway

obtained during maximal pre-excitation, which often requires atrial pacing. Our study shows that the previously reported criteria for accessory pathway location cannot be applied accurately to the resting 12 lead electrocardiogram. Only 32% of the patients in our series showed concordance with the Gallagher and World Health Organisation criteria. Both sets of criteria were inaccurate for left free wall and posterior paraseptal pathway locations. The results obtained in patients with a QRS width of more than 120 ms were not different from those in patients with a width of less than 120 ms.

The results in our study differ from previous criteria^{2,3} as follows: (a) a negative delta wave or a Q wave in V6 rarely occurs and should not be considered necessary for locating a left lateral or left posterior accessory pathway^{2,3,27,28}; (b) inferior leads II, III, and aVF often have a positive delta wave in the left lateral and left posterior accessory pathway^{27,28}; (c) a negative QRS complex in leads V1 and III does not permit right lateral and right posterior accessory pathways to be discriminated; and (c) the combination of a positive QRS complex in lead V1 and a negative QRS complex in lead III rarely occurs with a left posterior accessory pathway.

The limitations of our study are as follows: (a) in 15 of the 47 patients the delta wave was not analysed simultaneously in any lead, but great care was taken to analyse the first 40 ms of ventricular activation in each lead; and (b) the number of right-sided accessory pathways was small and no patients with anterior septal pathways were evaluated.

Clinical implications

The resting 12 lead electrocardiogram is not helpful for identifying the precise location of an accessory pathway by published criteria. If such information is required, detailed electrophysiological testing should be performed.

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