Right ventricular abnormalities in ventricular tachycardia of right ventricular origin: relation to electrophysiological abnormalities

R A FOALE, P NIHOYANNOPOULOS, P RIBEIRO, W J McKENNA, C M OAKLEY, D M KRIKLER, E ROWLAND*

From the Division of Cardiovascular Disease, Royal Postgraduate Medical School, Hammersmith Hospital, and the Department of Cardiology, St Mary's Hospital, London

SUMMARY Patients with right ventricular tachycardia may have adverse electrophysiological abnormalities linked to disturbed right ventricular structure. Seventeen patients who presented with right ventricular tachycardia without coronary artery disease or gross abnormalities of left ventricular function were studied. Patients had the ventricular tachycardia characterised at electrophysiological study and most underwent radionuclide and contrast angiography. At echocardiography specific attention was paid to the right ventricular chamber size. Two groups were identified at echocardiographic study. In group 1, nine patients had normal left ventricular dimensions and relatively normal features at electrophysiological study. Mean right ventricular ejection fraction was 0.45 by krypton-81 measurement. Group 2 comprised eight patients who had dilatation of right ventricular inflow tract, outflow tract, and right ventricular body. This group had more severe features at presentation and at electrophysiological study. In this group all available echocardiographic measurements of right ventricular chamber size were greater than those of group 1 and outside the normal range. Four of the eight patients in group 2 showed regional right ventricular dyskinesia at echocardiography. Mean right ventricular ejection fraction (0.23) in group 2 was significantly lower than in group 1. One patient in group 2 subsequently died.

In patients with right ventricular tachycardia, those with less favourable prognostic features at electrophysiological study may have distinct abnormalities of right ventricular structure that can be identified at echocardiographic study. Echocardiography may be of value in the recognition of potentially malignant clinical and electrophysiological features in this group.

The right ventricle may be the seat of ventricular tachycardia of left bundle branch block pattern.^{1,2} Recent interest has centred on its pathophysiology because early reports suggested that an apparent absence of gross organic heart disease indicated a more favourable prognosis.²⁻⁴ Others have demonstrated that right ventricular tachycardia can have adverse electrophysiological features and may be associated with right sided structural disorders. These include right ventricular dysplasia⁵ and coro-

nary artery disease and cardiomyopathy affecting one or both ventricles.⁶ Thus in patients with right ventricular tachycardia who do not have gross left ventricular or coronary heart disease identification of a right ventricular abnormality may be important for recognising those with adverse electrophysiological features and perhaps a less favourable prognosis.⁷

Precise evaluation of the right ventricle may, however, be difficult because isolated right ventricular dysfunction may not be associated with obvious clinical signs or result in any easily defined abnormality detectable by routine non-invasive and angiographic methods.⁸ In this study we have used echocardiography, with emphasis on specific right ventricular views, to describe right ventricular mor-

Requests for reprints to Dr Rodney Foale, St Mary's Hospital, Praed Street, London W2 1NY.

*Present address: National Heart Hospital, Westmoreland Street, London W1.

Accepted for publication 24 February 1986

Table 1 Clinical details

Case	Age (yr)	Sex	Main symptoms				Chest x ray	ECG	Symptoms before first seen (mnth)	Follow up period (mnth)
			Palp	Presyncope	Syncope	Other				
Group 1:										
1	50	M	+	—	—	—	N	N	6	3
2	54	F	+	—	—	SOB	N	N	14	13
3	49	F	+	+	+	—	N	N	34	9
4	36	M	+	—	—	CP	N	T↓, II, IIIa, aVF	149	124
5	60	M	+	+	—	—	N	N	129	19
6	52	F	+	—	—	—	N	N	204	34
7	50	F	+	+	—	—	N	T flat, V1-4	84	55
8	40	F	+	+	—	—	N	N	44	4
9	24	M	+	+	—	CP	N	N	12	44
Mean	48	4M/5F	9	5	1	—	—	—	75	34
Group 2:										
10	17	M	+	+	+	CP	RV+	T↓, V1-6	184	59
11	21	M	+	+	—	CP	RV+	T↓, V1-4	42	49
12	23	M	+	+	+	—	N	T↓, V1-4 and II, III, aVF	164	54
13	22	M	+	+	+	CP	RV+	T↓, V1-4	29	2
14	42	M	+	+	+	—	N	T flat V1-6	47	54
15	33	F	+	+	+	CP	N	T↓, V1-4	4	1
16	30	M	+	+	+	CP	N	N	104	49
17*	28	M	+	+	+	—	N	T↓, V1-3	64	12
Mean	21	7M/1F	8	8	7	—	—	—	80	35

Palp, palpitation; ECG, 12 lead electrocardiogram; N, normal; SOB, short of breath; CP, chest pain; T↓, T wave inversion; RV+, radiological right ventricular enlargement.

*Died.

phology in relation to the clinical and electrophysiological findings in 17 patients presenting with ventricular tachycardia of right sided origin.

Patients and methods

The study group comprised 17 patients with ventricular tachycardia. Table 1 shows their clinical details. Five patients (cases 10-14) in this series were described in our earlier report.⁷ In each of the 17 patients a 12 lead electrocardiogram showed that during ventricular tachycardia the QRS configuration was of a left bundle branch block pattern. A detailed clinical evaluation and chest x ray with resting 12 lead electrocardiogram were available from each patient.

Additional investigations were performed to characterise the ventricular tachycardia and to evaluate right ventricular anatomy. These included right sided electrophysiological study, radionuclide angiography, and cardiac catheterisation with contrast ventriculography and coronary arteriography. Patients who had presented with right ventricular tachycardia but with coronary artery or overt left ventricular disease or both were excluded.

ELECTROPHYSIOLOGICAL STUDIES

Electrophysiological tests were undertaken in all but one patient (case 17) who died suddenly before this investigation was undertaken. Three patients were taking amiodarone and in these patients the studies were performed to assess alternative therapeutic reg-

imens because amiodarone alone had failed to control the arrhythmia. Two patients (cases 4 and 5) underwent electrophysiological study during spontaneous episodes of arrhythmia. In 16 patients right ventricular endocardial mapping was performed to localise the origin of the ventricular tachycardia.

RADIONUCLIDE ANGIOGRAPHY

A radionuclide study of the left ventricle that used red blood cells labelled in vivo with technetium-99m was available in 14 patients (cases 1, 3, 4, 6-16). Multigated images were obtained in the anterior and left anterior oblique projections. In 15 patients (cases 1, 3-16) a radionuclide study of the right ventricle was performed with krypton-81m. Multigated images were obtained in the anteroposterior projection. Global left and right ventricular function was assessed by ejection fraction and was measured according to the protocol used in our laboratory.⁹

CARDIAC CATHETERISATION AND CONTRAST VENTRICULOGRAPHY

Cardiac catheterisation and contrast ventriculography of the left heart in 13 patients (cases 1-6, 10-15, 17) and of the right heart in 14 patients (cases 1-6, 10-17) was performed by a transfemoral percutaneous approach. Resting intracardiac pressures were recorded and particular attention was paid to left and right ventricular end diastolic values. Left ventriculography was performed in a 45° right anterior oblique projection with 0.3-0.5 ml/kg of contrast agent (Conray, Eli Lilly) injected at a rate of

12 ml/s. Right ventriculography was performed in the anteroposterior or 10° right anterior oblique projections or both with a similar amount of contrast agent. Care was taken to position the catheter towards the apex of the right ventricle and to avoid ventricular extrasystoles at the time of injection. Coronary angiography was performed in ten patients in whom a history of chest pain or another feature was considered to require exclusion of coronary artery disease.

ECHOCARDIOGRAPHIC METHODS

Echocardiograms were obtained prospectively in 16 patients by means of a high resolution M mode and cross sectional dual display cardiac ultrasound system (Pass C, International General Electric Company, Slough, Berkshire, UK). A 3.3 MHz transducer, dynamically focused throughout the depth of field was used. In each of these 16 patients the studies were performed without knowledge of the clinical, angiographic, or electrophysiological features. In one patient (case 17) only an M mode echocardiogram was available. This preliminary study had been performed with a 2.25 MHz transducer focused at 5 cm (Cardioscan IV, Irex Medical Systems, UK). The study was of a high technical quality and was included in retrospect because of the clinical importance of the case.

Dual display M mode and cross sectional echocardiographic studies were recorded on to videotape for subsequent analysis. Measurements were performed on an offline microcomputer system (Microsonics Company, Indianapolis, Indiana, USA). All measurements were made from end diastolic frames by one experienced observer. Internal cavity dimensions were taken from endocardial borders and a leading edge to leading edge criterion was used to define cavity boundaries. Values from three consecutive cardiac cycles recorded in held expiration were averaged and we used this value in the final analysis. In cases 1–16 we used a standardised sequence for the examination of the heart and directed attention to the right ventricle.¹⁰ From this detailed evaluation of right ventricular chamber size at the inflow tract, body, and outflow tract regions we first selected three different measurements of the right ventricular outflow tract (Fig. 1). RVOT₁ is the proximal region of the outflow tract seen in the parasternal long axis view of the left ventricle. RVOT₂ and RVOT₃ are measurements of the mid and distal regions of the right ventricular outflow tract in the parasternal right ventricular outflow tract view.¹⁰ Secondly, we selected measurements of three different orientations of the right ventricular inflow tract (Fig. 1). RVIT₁ was the measurement obtained in the parasternal right ventricular inflow tract view.

Fig. 1 Views from which right ventricular cavity measurements were performed (see text). (a and b) Outflow tract: RVOT₁, from parasternal long axis view of the left heart; RVOT₂ and RVOT₃, from the specific parasternal outflow tract view. (c, d, and e) Inflow tract: RVIT₁, from the specific parasternal inflow tract view; RVIT₂, from the parasternal short axis view of the tricuspid and mitral valves; RVIT₃, from the apical four chamber view. (e) RV body: RVB, also from the apical four chamber view. RVOT, right ventricular outflow tract; RVIT, right ventricular inflow tract; RVB, right ventricular body; LV, left ventricle; LA, left atrium; Ao, aorta; RA, right atrium.

RVIT₂ was obtained by a medial orientation from a parasternal short axis view of the mitral valve. RVIT₃ was taken from a standard apical four chamber view.¹¹ Finally the mid region of the right ventricular cavity (RVB) was measured from this latter projection (Fig. 1) to provide a single dimension for the right ventricular body.

In case 17, M mode echocardiography alone was available (Fig. 2a). It is clear, however, that the right ventricular cavity dimension obtained was equivalent to the proximal region of the right ventricular outflow tract (RVOT₁), as illustrated for example in case 10 in whom we had dual display M mode and cross sectional echocardiography from the parasternal long axis view of the left ventricle (Fig. 2b). From each of the views used in the study we subjectively evaluated right ventricular regional wall motion. Regional wall motion was considered to be

Fig. 2 (a) *M mode* echocardiogram from case 17. Note the dilated RV with a measurement equivalent to RVOT. (b) Dual display *M mode* and cross sectional echocardiographic image showing the equivalent *M mode* measurement of the proximal right ventricular outflow tract (RVOT₁) imaged from the parasternal long axis view (case 10). See legend to Fig. 1 for abbreviations.

abnormal when regions of systolic thinning and abnormal systolic motion were clearly seen in studies viewed in real time.

The patients were then classified into one of two groups according to whether there was echocardiographic evidence of right ventricular

dilatation. Group 1 comprised patients with cavity measurements within our reported normal range.¹⁰ Patients were classified as belonging to group 2 when one or more measurements of right ventricular chamber dimensions at inflow tract, body, or outflow tract fell outside the 95% confidence limits of our normal range. Thus a patient with just one abnormal measurement would be classified as falling into group 2.

All values were expressed as the mean (SD). We used Student's *t* test to compare groups 1 and 2.

Results

Of the 17 patients nine were classified as belonging to group 1 and eight to group 2 (Table 2). For the

Fig. 3 Measurements from the three regions of the right ventricle: RVOT, RVIT, and RVB. See Fig. 1 for abbreviations.

Table 2 Echocardiographic results in 17 patients

RV region	Group 1										Mean	SD
	1	2	3	4	5	6	7	8	9			
RVOT ₁	2.8	2.8	3.8	3.0	2.9	2.9	2.6	2.7	2.8	2.8	0.1	
RVOT ₂	2.1	2.2	2.0	1.7	1.7	2.3	1.9	2.5	2.1	2.0	0.3	
RVOT ₃	2.1	2.6	2.0	1.9	2.0	2.9	2.4	2.8	2.4	2.4	0.4	
RVIT ₁	5.8	6.1	4.2	5.8	5.7	5.1	4.4	5.5	5.2	5.3	0.7	
RVIT ₂	2.9	2.5	2.2	3.2	2.8	3.0	2.1	2.5	2.7	2.6	0.4	
RVIT ₃	3.2	3.2	3.1	3.5	3.1	2.2	3.2	3.2	3.4	3.2	0.1	
RVB	3.0	2.5	2.8	3.1	2.7	3.0	2.6	2.6	2.8	2.8	0.2	
RV RWMA	—	—	—	—	—	—	—	—	—	—	—	

*RV dimensions measurements of patients in group 2 within one standard deviation of group 1.

RV, right ventricle; RVOT, right ventricular outflow tract; RVIT, right ventricular inflow tract; RVB, right ventricular body; RWMA, wall motion abnormality; IT, inflow tract; OT, outflow tract; AP, apex; na, not available.

Fig. 4 The two views from which measurements of RVOT were made. (a) The parasternal long axis view of the left heart and (b) the specific parasternal long axis view of the right ventricular outflow tract. Measurements RVOT₁, RVOT₂, and RVOT₃ are all above the normal range in case 12 (see text). PA, pulmonary artery; other abbreviations are given in Fig. 1.

normal group 1, the three right ventricular outflow tract measurements were 2.8 (0.1) cm (mean (SD), 2.0 (0.3) cm, and 2.4 (0.4) cm for RVOT₁, RVOT₂, and RVOT₃. All were significantly lower than the same measurements for the eight patients in group 2 (Fig. 3). In group 2 measurements for RVOT₁, RVOT₂, and RVOT₃ were 4.0 (0.6) cm ($p < 0.005$), 3.3 (0.6) cm ($p < 0.001$), and 3.6 (0.6) cm ($p < 0.001$) respectively. Similarly the three measurements of inflow tract in group 1 were lower than for group 2, being 5.3 (0.7) cm, 2.6 (0.4) cm, and 3.2 (0.1) cm for RVIT₁, RVIT₂, and RVIT₃ compared with 7.1 (0.5) cm ($p < 0.001$), 4.4 (0.6) cm ($p < 0.001$), and

5.2 (1.0) cm ($p < 0.001$) respectively. The measurement of right ventricular body was also normal for group 1 (2.8 (0.2) cm) compared with group 2 (4.8 (1.1) cm, $p < 0.005$). Figures 4 and 5 show the cross sectional echocardiographic findings that typified group 2. In Fig. 4 the generalised dilatation of the outflow tract of case 16 is shown by abnormal RVOT₁, RVOT₂, and RVOT₃ cavity dimensions from parasternal long axis and specific right ventricular outflow tract views. In a second patient of group 2 (case 12) (Fig. 5) two abnormal right ventricular inflow tract dimensions and the measurement of right ventricu-

2									
11	12	13	14	15	16	17	Mean	SD	Range
4.2	3.9	3.9	5.0	3.2*	4.3	4.6	4.0	0.6	3.0–5.0
2.6	2.8	3.7	4.2	3.1	3.1	na	3.3	0.6	2.6–4.3
3.7	3.8	3.8	na	3.1	3.9	na	3.6	0.5	2.8–4.1
6.3	7.6	7.4	6.6	7.5	7.0	na	7.1	0.5	6.3–7.6
4.4	4.0	4.0	5.9	4.1	4.2	na	4.4	0.6	4.0–5.9
3.8	5.1	5.2	6.5	4.3	5.8	na	5.2	1.0	3.8–6.5
3.5	4.2	5.3	6.5	3.8	5.1	na	4.8	1.1	3.5–6.5
IT	OT	OT	—	AP	—	—	—	—	—

Fig. 5 Right ventricular inflow tract and right ventricular body measurements (case 12) taken from (a) the specific parasternal right ventricular inflow tract view (RVIT₁), (b) the parasternal short axis view of the mitral and tricuspid valve (RVIT₂), and (c) the apical four chamber view (RVIT₃ and RVB). TV, tricuspid valve; other abbreviations are given in Fig. 1.

lar body are shown.

All eight patients in group 2 had cavity dilatation of each region of the right ventricle (inflow tract, body, and outflow tract) measured from at least one dimension. Only three measurements in two patients from this group fell within our normal range. In case 10 two of the three measurements of right ventricular outflow tract were normal, and in case 15 one of these three measurements fell within our normal range. Each of these patients had less prominent dilatation of the outflow tract than of the inflow tract and right ventricular body. Furthermore, cases 10 and 15 showed dyskinetic segments of the inflow and apical segments of the right ventricle. Regional dyskinesia was also a feature of the studies from cases 11, 12, and 13 (Table 2).

In two patients (cases 12 and 13) an exaggerated trabecular appearance was present at the anterior aspect of the right ventricular cavity when viewed from serial short axis parasternal views (Fig. 6). In both these patients a honeycombed appearance was present in this region at right contrast ventriculography. The gross appearance of the left ventricle was normal by echocardiography in all patients of both groups.

The echocardiographic findings were consistent with both the radionuclide and contrast angiographic descriptions of the left and right ventricles (Table 3). In both groups the mean radionuclide left

Fig. 6 Abnormal trabecular pattern (arrows) seen in the anterior region of the right ventricular cavity and involving the interventricular septum; seen from serial short axis views of the left ventricle from mitral valve level (top) to left ventricular papillary muscles (below).

ventricular ejection fraction was normal and did not differ between the groups (0.54 vs 0.57). One patient in group 2, however, had a left ventricular ejection fraction of 0.34, just below our normal range (0.36–0.75). In patients from group 1 the mean radionuclide right ventricular ejection fraction was 0.45, compared with 0.23 in patients from group 2 ($p < 0.001$). The range of abnormal right ventricular ejection fractions in group 2 was 0.21–0.32 compared with the normal range from our laboratory of 0.38–0.55 ($p < 0.001$).

At cardiac catheterisation right ventricular pres-

Table 3 Results of special tests

Case no	Radiomulide EF		Intracardiac pressures		Angiography		Cor art
	LV Tc ^{99m}	RV K ^{88m}	LV S/LVED	RV S/RVED	RV	LV	
Group 1:							
1	0.52	0.51	120/12	30/6	N	N	N
2	ND	ND	110/8	25/4	N	N	N
3	0.59	0.47	105/8	27/6	N	N	N
4	0.45	0.43	110/8	24/6	N	N	N
5	ND	0.43	140/7	30/4	N	N	N
6	0.73	0.45	110/6	28/4	N	N	N
7	0.57	0.46	ND	ND	ND	ND	ND
8	0.62	0.37	ND	ND	ND	ND	ND
9	0.50	0.48	ND	ND	ND	ND	ND
Mean	0.54	0.45	EDP 7.2	5.0			
Group 2:							
10	0.50	0.21	115/10	26/5	RV dilated	N	N
11	0.72	0.20	120/10	25/7	RV dilated	N	ND
12	0.66	0.18	110/7	20/5	RV dilated	N	ND
13	0.60	0.26	130/8	45/20	RV dilated, RWMA	N	ND
14	0.34	0.24	110/15	24/8	RV dilated, RWMA	N	N
15	0.58	0.32	115/8	32/7	RV dilated, RWMA	N	N
16	0.46	0.20	ND	50/20	RV dilated, RWMA	N	N
17	ND	ND	120/7	30/4	RV dilated	N	N
Mean	0.57	0.23	EDP 9.3	9.5			

EF, ejection fraction; LV, left ventricle; RV, right ventricle; RWMA, regional wall motion abnormality; S, systolic; LVED, left ventricular end diastolic pressure; RVED, right ventricular end diastolic pressure; cor art, coronary arteriography; N, normal; ND, not done.

tures recorded from six patients in group 1 were all normal at rest. In these patients left heart pressures were also normal. In group 2 two patients had a raised right ventricular end diastolic pressure (cases 13 and 16). In the remaining six patients right ventricular pressures were normal at rest. The seven patients of group 2 in whom resting left ventricular pressures were recorded had normal values.

In group 1 right and left ventricular angiography performed in six patients was normal. In group 2 the right ventriculogram was abnormal in all eight patients. The appearances varied from a generalised dilatation of the cavity with mild but uniformly impaired contraction (case 10) to a bizarre ventricular shape abnormality with a honeycombed appearance (cases 12 and 13). Coronary arteriography was normal in the ten patients studied.

The clinical features, including the presentation of the patients, paralleled the echocardiographic findings, in that two main groups were identified

(Table 1 and 4). The nine patients in group 1 had a mean age of 48 years and were more likely to be female. Although palpitation was the dominant complaint at presentation in patients from both groups, in group 1 this was usually self limited, although it was associated with presyncope in five patients and syncope in one. Group 2 patients were young (mean age 21 years) ($p < 0.01$). Seven of the eight patients in group 2 had syncope (three had required resuscitation from ventricular fibrillation). A fourth patient (case 17) with previously documented ventricular tachycardia died suddenly. There was no difference in the mean length of symptoms before presentation (75 months *vs* 80 months) and the mean follow up (34 months *vs* 35 months) between groups 1 and 2 respectively.

All group 1 patients had a normal chest x ray. Two patients had minor precordial T wave changes on the resting 12 lead electrocardiogram, one in inferior leads and the second over precordial leads V1-V4. In

Table 4 Comparison between groups 1 and 2

Data	Group 1 (n=9)	Group 2 (n=8)	p
Mean age (yr)	48	21	0.01
Range (yr)	24-60	17-42	
Sex ratio (M:F)	4.5	7.1	0.01
Presyncope	5	8	NS
Syncope	1	7	0.05
Chest x ray abnormal	0	3	NS
Electrocardiogram abnormal	2	7	0.01
Mean length of symptoms (mnth)	75	80	NS
Mean follow up (mnth)	34	35	NS

Table 5 Results of electrophysiological study

Case no	Ventricular tachycardia			Ventricular fibrillation
	Inducibility	Rate (beats/min)	Sustained	
Group 1:				
1	NI	—	—	—
2	I	171	S	—
3	I	200	S	—
4*	NI	—	—	—
5*	NI	—	—	—
6	I	150	NS	—
7	I	185	NS	—
8	NI	—	—	—
9	I	280	NS	—
Mean		183		
Group 2:				
10	I	160–230	S	—
11	I	214–222	S	+
12	I	214–230	S	—
13	I	200–210	S	—
14	I	188	S	+
15	I	182	S	+
16	I	240	S	—
17	ND	ND	ND	Sudden death
Mean		209 (p, NS)		

I, inducible; NI, not inducible; ND, not done; S, sustained; NS, not sustained.

group 2, three patients had a slightly enlarged cardiac contour on plain chest x ray. In these patients the right heart border appeared to be prominent on the posteroanterior projection. All patients in group 2 had some abnormality of the electrocardiogram. Seven patients had T wave abnormalities over the right precordial leads V1–V3.

COMPARISON OF ECHOCARDIOGRAPHIC AND ELECTROPHYSIOLOGICAL FEATURES

The echocardiographic classification of two patient groups was closely paralleled by the findings from electrophysiological studies (Table 5). Group 1 patients were characterised by more benign electrophysiological features. In patients of this group, the ventricular tachycardia was of single QRS configuration and could be initiated in five patients only. Initiation of the tachycardia was usually difficult and required multiple programmed ventricular stimuli. Degeneration into ventricular fibrillation did not occur in any patient. The mean rate of tachycardia (183 (24) beats/min (mean (SD))), however, was not significantly different from that in group 2 patients (209 (26)). Patients in group 2 had more serious features at electrophysiological testing. Tachycardia with multiple sites of origin was more easily invoked in the six patients that we tested in group 2. In three patients spontaneous degeneration into ventricular fibrillation occurred that required cardioversion.

Discussion

In this study of right ventricular tachycardia we

identified two distinct patient groups—those with normal right ventricular chambers and those with dilated right ventricular chambers. Those patients with right ventricular dilatation appeared to have a less benign clinical presentation than those in whom the right ventricle was normal. These clinical features accorded with the less favourable findings at electrophysiological study. Thus the recognition of right ventricular dilatation in patients presenting with right ventricular tachycardia may prove useful in identifying those at risk from serious arrhythmia.

We have also shown that although radionuclide and contrast ventriculography can be used to identify right ventricular abnormality in this group, this determination can equally well be achieved with safety and convenience by echocardiography. M mode and/or cross sectional echocardiography have clear advantages particularly when access to specialised radionuclide and cardiac catheterisation facilities may be limited.

Froment and his colleagues first suggested that ventricular tachycardia with left bundle branch block morphology may indicate origin from the right ventricle.¹² Subsequently, electrophysiological studies have shown that the attribution of a right sided origin to this morphology of ventricular tachycardia may not always be valid^{13 14}; however, in the absence of overt left ventricular or coronary heart disease, such as with our selected patient population, this is a generally useful guide.¹² Early reports of patients with right ventricular tachycardia suggested that this group has a favourable prognosis and infrequent overt cardiac abnormality.^{2–4 6 15} One study, however, excluded patients with any “ventricular

dysfunction" by various invasive and non-invasive methods.¹⁵ Another excluded patients with more than one site for the ventricular tachycardia.⁶ Other groups¹ including our own⁷ have examined a specific population of patients with right ventricular tachycardia selected for the presence of structural heart abnormality and have drawn attention to the unfavourable electrophysiological observations encountered in patients in this group.

In the present study, patients with ventricular tachycardia of left bundle branch block pattern were selected only on the basis of excluding left ventricular disease. Given this criterion, we have shown a clear bimodal distribution of right ventricular anatomy in these patients that appears to be closely linked to clinical and electrophysiological findings.

In group 1 the clinical spectrum was more varied and the common denominators were benign electrophysiological features and normal right ventricular structure. Patients in group 2 were more uniform with presyncope or syncope as part of the clinical presentation and they had less favourable prognostic results at electrophysiological testing. The clinical features, electrophysiological tests, and right ventricular abnormality of some patients in group 2 were undoubtedly consistent with a diagnosis of arrhythmogenic right ventricular dysplasia, first described by Fontaine *et al.*⁵ These patients are young, predominantly male, and have non-specific T wave changes over right ventricular precordial leads. The chest x ray may show a prominent right heart border and the abnormalities of right ventricular anatomy of some patients in group 2 appear to be identical with the cases observed by Fontaine *et al.*⁵ Furthermore, a right ventricular regional wall motion abnormality, recognised at echocardiography in five of our group 2 patients, lends support to this diagnosis. This diagnosis, however, has only been substantiated in one patient at operation. In other patients of group 2, echocardiography, supported by the appearance of right ventricular contrast angiography, showed a more generalised dilatation of the right ventricular cavity. In this group a more diffuse myocardial abnormality compatible with right ventricular cardiomyopathy might be the diagnosis.^{16 17} Our data lack pathological support. Apart from direct inspection at operation, however, it is probable that this may only properly be documented at necropsy. This was not undertaken in the one patient in our series who died suddenly. Of the remainder who underwent successful myocardial biopsy at cardiac catheterisation, only features of non-specific myocardial injury or normal histology were described.

Our population was selected as far as possible to exclude dominant left ventricular or coronary arterial disease. One patient (case 14) had a reduction of

left ventricular ejection fraction as judged by radio-nuclide study. Contrast left ventriculography and echocardiography, however, demonstrated normal left ventricular function. One explanation for this finding may be that an occult form of left ventricular dysfunction is present in some patients with apparently isolated right ventricular disease. Because dilated cardiomyopathy embraces a broad spectrum of pathogenetic mechanisms and functional effects, it may be that in patients with "borderline" normal left ventricular function such a discrepancy is accounted for by the performance of the studies under slightly different conditions. This view accords with a recent report which showed that important exercise induced abnormalities of left ventricular function could be produced in patients with arrhythmogenic right ventricular dysplasia.¹⁸

The use of echocardiography to evaluate patients suspected of having right ventricular abnormality has attractions. Our experience is that use of the present generation high resolution ultrasound systems facilitates the imaging of the right ventricle particularly when specific right ventricular views are used as part of the normal sequence of examination.¹⁰ The ultrasound system used in this study has a small transducer that can be positioned between the intercostal spaces. Thus the angulated orientations necessary to obtain specific right ventricular views may be better achieved. Other earlier reports have recognised that echocardiography may be useful in identifying the right ventricular abnormalities in patients with right ventricular tachycardia. The experience of this study confirms our preliminary report of five patients in whom echocardiography identified right ventricular cavity dilatation.⁷ Other investigators have used echocardiography in isolated cases to detect right ventricular enlargement and regional abnormalities in right ventricular tachycardia.¹⁸⁻²¹ In one, attention was drawn to the important distinction of Ebstein's anomaly that is easily made with echocardiography and which must be considered in the differential diagnosis of this group. We draw attention to the importance of using more than one transducer location when performing an echocardiographic study of the right ventricle. When single transducer locations are used the eccentric geometry of the right ventricle makes a confident exclusion of right ventricular disease difficult. This is particularly true in a population such as the one under study which may show regional abnormalities.

Modern echocardiographic techniques may be useful in the evaluation of right ventricular chamber size and regional wall abnormalities in patients with right ventricular tachycardia. The method is more generally available than specialised radionuclide or

catheterisation studies and is safe. Furthermore, by identifying right ventricular chamber dilatation in patients in whom a right ventricular origin for ventricular tachycardia is suspected, the method might predict those patients at potential risk of serious and life threatening arrhythmia.

References

- 1 Reiter MJ, Smith WM, Gallagher JJ. Clinical spectrum of ventricular tachycardia with left bundle branch morphology. *Am J Cardiol* 1983; 51: 113–21.
- 2 Pietras RJ, Mautner R, Denes P, *et al.* Chronic recurrent right and left ventricular tachycardia: comparison of clinical, haemodynamic and angiographic findings. *Am J Cardiol* 1977; 40: 32–7.
- 3 Manning GW, Ahuja SP, Gutierrez MR. Electrocardiographic differentiation between ventricular ectopic beats from subjects with normal and diseased hearts. *Acta Cardiol (Brux)* 1978; 23: 462–70.
- 4 Bodenheimer MM, Banka VS, Helfant RH. Relation between the site of origin of ventricular premature complexes and the presence and severity of coronary artery disease. *Am J Cardiol* 1977; 40: 865–9.
- 5 Fontaine G, Guiraudon G, Frank R, *et al.* Stimulation studies and epicardial mapping in ventricular tachycardia; study of mechanisms and selection for surgery. In: Kulbertus HE, ed. *Reentrant arrhythmias: mechanisms and treatment*. Lancaster: MTP, 1977: 334–50.
- 6 Pietras RJ, Lam W, Bauernfeind R, *et al.* Chronic recurrent right ventricular tachycardia in patients without ischaemic heart disease: clinical, hemodynamic and angiographic findings. *Am Heart J* 1983; 105: 357–66.
- 7 Rowland E, McKenna WJ, Sugrue D, Barclay R, Foale RA, Krikler DM. Ventricular tachycardia of left bundle branch block configuration in patients with isolated ventricular dilatation: clinical and electrophysiological features. *Br Heart J* 1984; 51: 15–24.
- 8 Walton S. Noninvasive evaluation of right ventricular function. *Transactions of Royal Society of Medicine* 1983; 76: 337–9.
- 9 Sugrue DD, Kamal S, Deanfield JE, *et al.* Assessment of right ventricular function and anatomy using peripheral vein infusion of krypton-81m. *Br J Radiol* 1983; 56: 657–63.
- 10 Foale R, Nihoyannopoulos P, McKenna W, *et al.* Echocardiographic measurement of the normal adult right ventricle. *Br Heart J* 1986; 56: 33–44.
- 11 Weyman AE. *Cross-sectional echocardiography*. Philadelphia: Lea and Febiger, 1982: 63–89.
- 12 Froment R, Gallavardin L, Cahen P. Paroxysmal ventricular tachycardia. A clinical classification. *Br Heart J* 1953; 15: 172–8.
- 13 Josephson ME, Horowitz LN, Farshidi A, *et al.* Recurrent sustained ventricular tachycardia. 4. Pleomorphism. *Circulation* 1979; 59: 459–68.
- 14 Kaplinsky E, Ogawa S, Kmetzo J, Dreifus LS. Origin of so-called right and left ventricular arrhythmias in acute myocardial ischemia. *Am J Cardiol* 1978; 42: 774–80.
- 15 Buxton AE, Waxman HL, Marchlinski FE, *et al.* Right ventricular tachycardia: clinical and electrophysiologic characteristics. *Circulation* 1983; 68: 917–27.
- 16 Fitchett DH, MacArthur CG, Oakley CM, *et al.* Right ventricular cardiomyopathy presenting with recurrent ventricular tachycardia. *Am J Cardiol* 1981; 47: 402–9.
- 17 Fitchett DH, Sugrue DD, MacArthur CG, Oakley CM. Right ventricular dilated cardiomyopathy. *Br Heart J* 1984; 51: 25–9.
- 18 Manyari DE, Klein GJ, Gulamhusein S, *et al.* Arrhythmogenic right ventricular dysplasia: a generalized cardiomyopathy? *Circulation* 1983; 68: 251–7.
- 19 Marcus FI, Fontaine GH, Guiraudon G, *et al.* Right ventricular dysplasia: a report of 24 adult cases. *Circulation* 1982; 65: 384–98.
- 20 Rossi P, Massomi A, Gillette P, Hall RJ. Arrhythmogenic right ventricular dysplasia: clinical features, diagnostic techniques, and current management. *Am Heart J* 1982; 10: 415–20.
- 21 Neimann JL. Les dysplasies ventriculaires droites. A propos de 7 observations. *Arch Mal Coeur* 1979; 7: 766–73.