Single-Catheter Approach to Radiofrequency Current Ablation of Left-Sided Accessory Pathways in Patients With Wolff-Parkinson-White Syndrome

Karl-Heinz Kuck, MD, and Michael Schlüter, PhD

Background. **Catheter ablation with the use of radiofrequency current has been introduced as a therapeutic option for patients with tachyarrhythmias mediated by an accessory atrioventricular pathway. The technique conventionally implies the introduction of several catheters into the heart for assessment of electrophysiological parameters as well as for localization of the accessory pathway and may last for several hours.**

Methods and Results. **Thirty-four patients with Wolff-Parkinson-White syndrome and a delta wave pattern indicative of an overt (i.e., capable of consistent antegrade conduction) left-sided free-wall accessory pathway underwent attempts at radiofrequency current ablation of the pathway with the use of just one catheter. No patient had a previous electrophysiological study. The catheter was introduced into the left ventricle close to the mitral annulus and was used for pathway localization as well as for ablation. The approach was completely successful in 30 patients (88%). In the remaining four patients, ablation of the pathway was achieved by using the multiple-catheter approach. Overall procedure duration was 2.0±1.1 hours; radiation exposure time was 22.8±20.4 minutes (median, 17.3 minutes). There were no acute complications.**

Conclusions. **The single-catheter approach to radiofrequency current ablation of overt left-sided free-wall accessory pathways is feasible, safe, and effective in the majority of patients. The approach requires considerable investigator experience but significantly reduces procedure duration and radiation exposure time. (*Circulation* 1991;84:2366–2375)**

Catheter ablation by radiofrequency current to control cardiac arrhythmias has been aimed at arrhythmogenic foci as well as at the physiological and pathophysiological paths of electrical activation through the heart.[1–6] Among the latter, catheter ablation of accessory atrioventricular pathways is at present more frequently attempted, the principal reasons being the high success rate reported from several centers and the possibility of avoiding cardiac surgery in severely symptomatic patients.[7,8] The technique is based on locating the accessory pathway by means of catheter mapping followed by the application of radiofrequency current to that site. Recent advances in catheter technology have enabled the direct recording of accessory pathway activation, and the search for accessory pathway potentials may now replace the recording of antegrade and/or retrograde activation sequences in the determination of accessory pathway sites.[9]

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For ablation of left-sided accessory pathways, we[10–13] proposed an arterial approach in 1986 in which the introduction of the ablation catheter into the left ventricle was used. The present article reports the extension of this approach to accessory pathway localization and ablation in patients with Wolff-Parkinson-White syndrome by using a single catheter.

Methods

Patients

Between May 1987 and June 1991, 150 consecutive patients underwent catheter ablation of an accessory pathway with the use of radiofrequency current in our department. Of these, 69 had Wolff-Parkinson-White syndrome on the basis of an overt left-sided free-wall accessory atrioventricular pathway capable of consistent antegrade and retrograde, or in four patients consistent antegrade only, conduction properties. Initially, all patients were studied with the

From the Department of Cardiology, University Hospital Eppendorf, Hamburg, FRG.

Address for correspondence: Karl-Heinz Kuck, MD, Department of Cardiology, University Hospital Eppendorf, Martinistrasse 52, 2000 Hamburg 20, FRG.

Received April 3, 1991; revision accepted July 30, 1991.

TABLE 1. Characteristics of 34 Single-Catheter-Group Patients

Pt No.	Age (yr)	Sex	AP loc	Symptoms	Drugs	Tachy type
1	42	M	L lat	Frq palp (86)	Baru, flec, sot	AVRT
2	50	F	L ant	Frq palp (50), presync	Meto, prjm, prpfn, sot	AVRT
3	63	M	L antlat	Frq palp	Prjm	AVRT
4	30	M	L lat	Frq palp (88), presync	Flec, sot	AVRT
5	52	F	L antlat	Presync (90)	Prjm	AFib
6	30	M	L antlat	Frq palp (75), CA	Meto, prjm, sot, ver	AVRT, AFib -> VF
7	39	F	L lat	Frq palp (70)	Prjm, sot	AVRT
8	34	F	L antlat	Frq palp (86), CA	β-Blk, sot	AFib -> VF
9	54	M	L lat	Frq palp (70)	Prjm, sot	AVRT
10	18	M	L post	CA (88)	None	AFib -> VF
11	54	M	L lat	Frq palp (78)	Aten, flec, prjm, prpfn, sot, ver	AVRT
12	26	M	L lat	Freq palp	None	AVRT
13	27	F	L antlat	Frq palp (82)	Ver	AVRT
14	67	M	L postlat	Frq palp (60)	Dig, flec, ver, β-blk	AVRT
15	34	M	L post	Sync, WPW surg 9/87, CA	Flec, prpfn, sot	AFib -> VF
16	19	M	L lat	Frq palp (88)	Ver	AVRT
17	51	M	L lat	Frq palp (63)	Dig, prjm, prpfn, sot, ver	AVRT
18	23	M	L lat	Frq palp (83)	Prjm	AVRT, AFib
19	38	M	L antlat	Frq palp (90)	Sot	AVRT, AFib
20	55	M	L lat	Frq palp (80)	Flec, prjm, sot	AVRT
21	34	F	L lat	Frq palp (72), presync	Flec, prjm, ver	AVRT
22	29	F	L antlat	Infrq palp (88)	None	AVRT
23	51	F	L postlat	Frq palp (66), ex dysp	Prjm, sot	AVRT, AFib
24	49	F	L antlat	Infrq palp (68)	Sot, ver	AVRT
25	43	M	L lat	Frq palp (82), presync, CA	Flec, prjm, prpfn, sot	AVRT, AFib
26	7	F	L lat	Frq palp (84)	Dig, flec, prpfn	AVRT
27	11	M	L lat	Infrq palp (88)	Prpnl	AVRT
28	22	M	L lat	Frq palp (79), presync, sync	Prjm, sot, ver	AVRT
29	46	M	L antlat	Infrq palp (childhood)	Ver	AVRT
30	30	F	L antlat	Frq palp (65), sync	Prjm, prpfn, sot	AVRT
31	56	M	L lat	Palp (66)	Prjm	AVRT
32	17	M	L lat	Frq palp (81), presync	Ver	AVRT
33	56	F	L lat	Frq palp (70), sync	Prjm	AVRT, AFib
34	45	M	L lat	Infrq palp (50)	None	AVRT

Numbers in parentheses in "Symptoms" column denote year of onset. Where no year is given, information was not available. AFib, atrial fibrillation; ant, anterior; antlat, anterolateral; AP, accessory pathway; aten, atenolol; AVRT, atrioventricular reentrant tachycardia; baru, barucainide; β-blk, beta blocker; CA, cardiac arrest; dig, digitalis; ex dysp, exertional dyspnea; F, female; flec, flecainide; frq, frequent; infrq, infrequent; L, left; lat, lateral; loc, location; M, male; meto, metoprolol; palp, palpitations; post, posterior; postlat, posterolateral; presync, presyncope; prjm, prajmaline; prpfn, propafenone; Pt, patient; sot, sotalol; surg, surgery; sync, syncope; Tachy, tachycardia; ver, verapamil; VF, ventricular fibrillation; yr, years.

standard multiple-catheter technique.[14] It was realized during these studies that the ventricular insertion site of the accessory pathway could be located as precisely with the left ventricular ablation catheter as with the coronary sinus mapping catheter used solely to guide the left ventricular catheter. It was then hypothesized that the introduction of right atrial and ventricular pacing catheters as well as His bundle and coronary sinus mapping catheters may not be necessary in these patients to achieve successful pathway ablation. To test this hypothesis, as of mid-July 1990, all patients with a clearly discernible delta wave pattern indicative of a left-sided free-wall accessory atrioventricular pathway underwent an attempt at ablation of their accessory pathway with the use of a single catheter introduced into the left ventricle. There were 34 patients (12 women, 22 men; age, 38±15 years; Table 1). The patients were free of organic heart disease, and in one, a previous surgical attempt at interruption of accessory pathway conduction had failed. All patients were symptomatic with symptoms ranging from frequent episodes of palpitations and dizziness to presyncope and cardiac arrest (in five patients). The underlying type of arrhythmia was atrioventricular reentrant tachycardia in 24 patients and atrial fibrillation in four. Six patients had a history of both arrhythmias. Drug trials with a median of two antiarrhythmic agents (range, 1–6) had

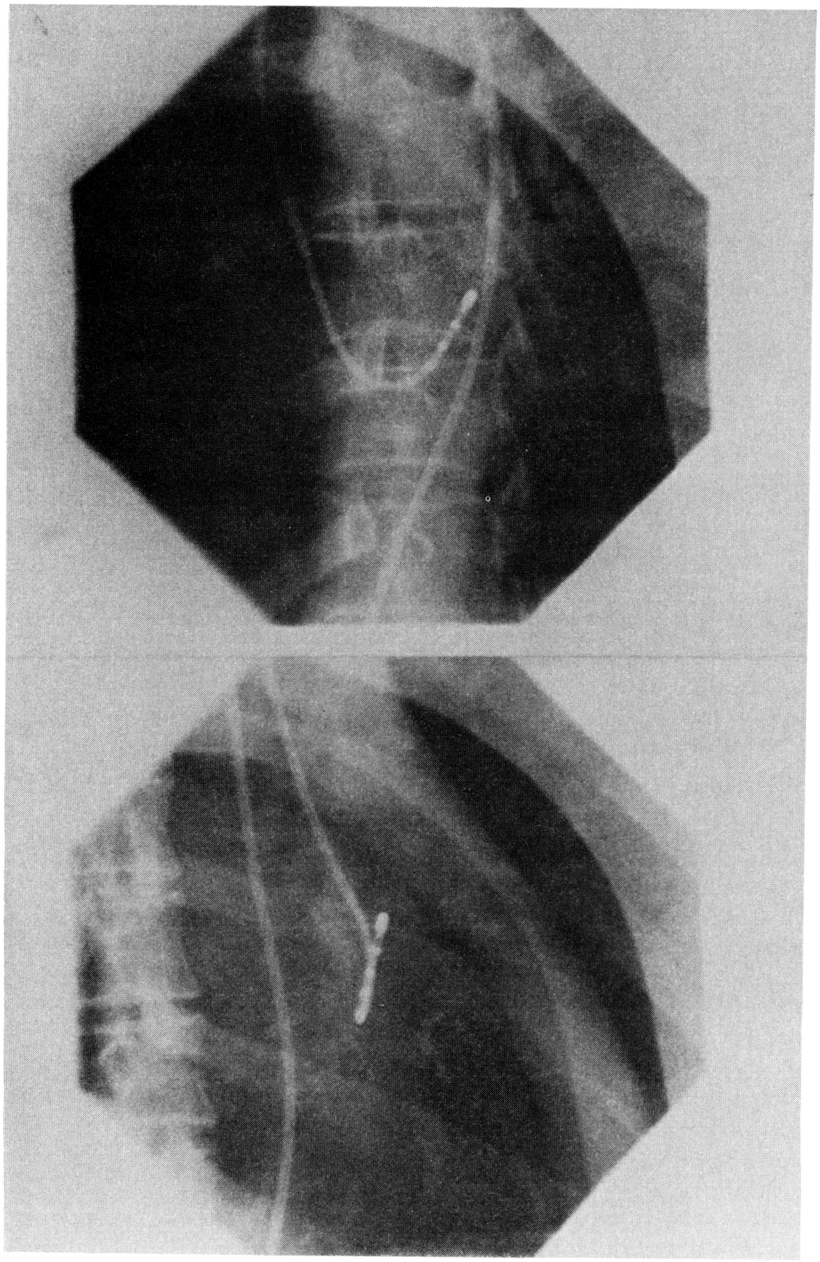

FIGURE 1. *Radiographs illustrating catheter position in the left ventricle below the mitral annulus. Tip electrode is placed left laterally at site of accessory pathway.* Top panel: *30° left anterior oblique view;* bottom panel: *30° right anterior oblique view.*

failed in 30 patients; the other four patients had not taken any antiarrhythmic medication before inclusion in this study. None of these patients had previously undergone a diagnostic electrophysiological investigation.

The other 35 patients with an overt left-sided free-wall accessory atrioventricular pathway (13 women, 22 men; age, 39±17 years) underwent the multiple-catheter approach to ablation of their accessory pathway. Twenty were studied before the single-catheter project was begun.

All patients were informed about the investigational nature of radiofrequency current catheter ablation and gave their written consent.

Strategy of Catheter Mapping and Ablation

In the patients who underwent the single-catheter approach, a venous sheath was inserted into the right femoral vein for heparinization and potential administration of sedative drugs. A steerable 7F quadripolar catheter with 5-mm interelectrode distance and a tip electrode of 4 mm length (Mansfield/Webster Catheters, Mansfield Scientific, Inc., Mansfield, Mass., or Dr. Osypka GmbH, Grenzach-Wyhlen, FRG) was then introduced via the right femoral artery into the left ventricle. The catheter was advanced under fluoroscopic guidance (30° right anterior oblique view) toward the mitral annulus and placed so that a bipolar electrogram recorded from

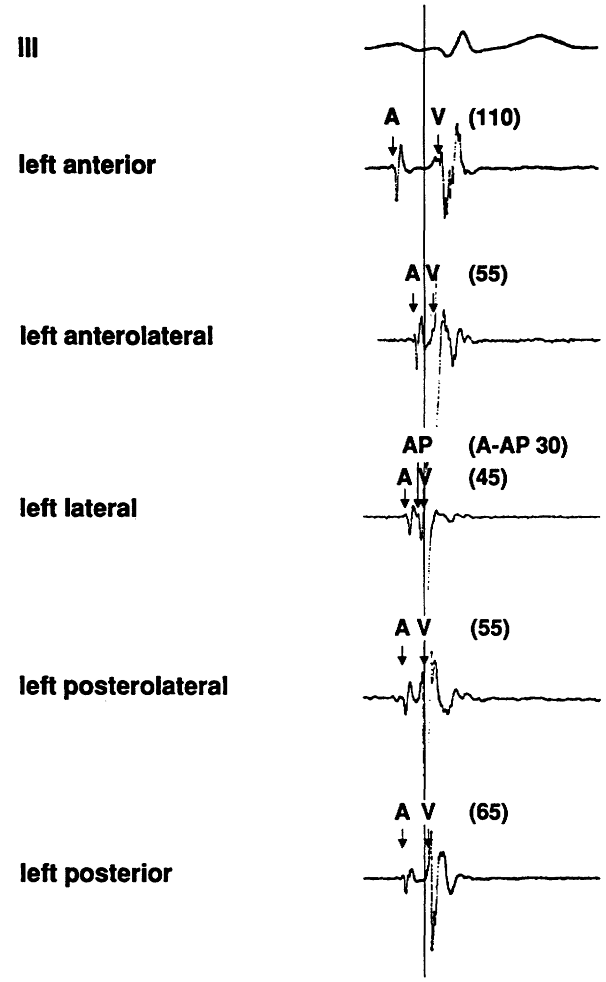

FIGURE 2. *Map of left free wall along mitral annulus recorded from left ventricular catheter in a patient with a left lateral accessory pathway. Shown are bipolar endocardial electrograms from five annular sites and surface electrocardiographic lead III. Vertical line denotes onset of the delta wave; numbers in parentheses represent, except where noted, local atrioventricular (AV) conduction times in milliseconds. Note the recording in the left lateral electrogram of the shortest AV interval (45 msec), which coincides with the appearance of an accessory pathway (AP) potential between the atrial (A) and ventricular (V) potential. The A-AP interval measures 30 msec.*

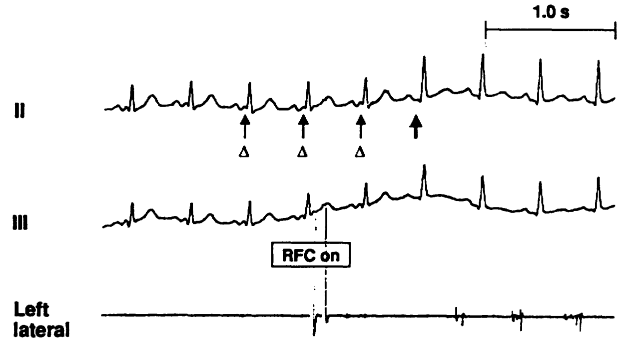

FIGURE 3. *Electrograms recorded from same patient as in Figure 1, showing application during sinus rhythm of radiofrequency current (RFC on) to left lateral site of accessory pathway. Note the almost immediate disappearance (heavy arrow) of the delta wave (Δ), indicating conduction block in the accessory pathway.*

the distal electrode pair revealed both a distinct ventricular as well as an atrial potential.[12] Final catheter placement for ablation was achieved in the 30° left anterior oblique view (Figure 1). To verify the catheter position as being as close to the mitral annulus as possible, it was required that the atrial potential was at least 25% in amplitude of the ventricular potential.[15]

The left ventricular catheter was used to search for presumed accessory pathway potentials in the annular region where the delta wave pattern of the patient's surface electrocardiogram suggested the location of the pathway.[16,17] Because just one catheter was used, the nature of the potential that was believed to originate from an accessory pathway could not be verified by stimulation techniques.[9,18] An accessory pathway potential was therefore assumed if a distinct potential after the local atrial potential was recorded that preceded or coincided with the onset of the delta wave and was followed by a third potential representing local ventricular activation (Figure 2). When such an accessory pathway potential was found, with an atrium accessory pathway interval of less than 30 msec, electrocoagulation was attempted without further mapping of the mitral annulus by delivering radiofrequency current during sinus rhythm between the distal catheter electrode (kept in place at the pathway site) and a patch electrode placed below the patient's left scapula (Figure 3).

When no accessory pathway activation potential could be recorded with the left ventricular catheter, the single-catheter approach was considered a failure and the conventional multi-catheter approach was attempted in these patients. To this end, an additional 6F catheter with three groups of four circumferential electrodes arranged in an orthogonal configuration (Jackman catheter; Mansfield/Webster Catheters) was positioned into the coronary sinus to search for accessory pathway potentials[9]; standard quadripolar catheters were advanced via the femoral veins to the bundle of His and, for stimulation purposes, to the right ventricular apex and the high right atrium. If precise accessory pathway localization was thus achieved, the distal electrode of the left ventricular catheter was placed opposite the coronary sinus catheter electrode that had located the accessory pathway. Radiofrequency current was then delivered in the unipolar fashion described above.

A generator supplying unmodulated 500-kHz alternating current (HAT 200, Dr. Osypka GmbH) was used for ablation attempts. With this generator, preset electrical power was held constant over a preset application time. Initial power setting was usually 25 W, to

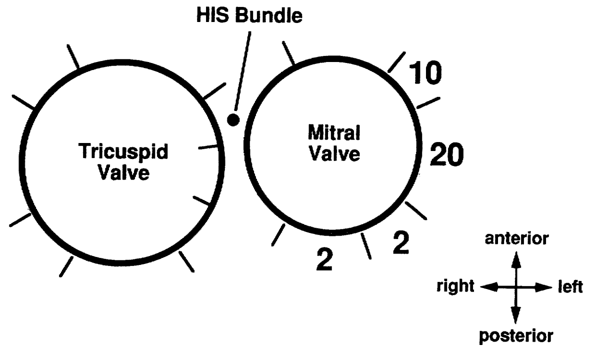

FIGURE 4. *Schematic diagram illustrating locations of 34 accessory pathways. For each location, total number of accessory pathways is given. On the left free wall, there were 10 anterolateral, 20 lateral, two posterolateral, and two posterior accessory pathways.*

be applied for 20 seconds. Relevant data of radiofrequency current delivery (power, duration, cumulative energy) were stored on a personal computer system which, however, does not provide for calculation of voltage, current, or impedance. Two surface leads (II and III) and one to three endocardial leads were recorded at 25 mm/sec on a 16-channel recorder (Mingograph, Siemens AG, Erlangen, FRG) during radiofrequency current delivery.

The ablation procedure was considered successful if antegrade accessory pathway conduction had been abolished, as judged by the disappearance of the delta wave. With the exception of patient 27, in whom the catheter was dislocated after the initial successful ablation attempt, successful ablation of an accessory pathway was followed (with the catheter remaining in place) by the application of one additional "safety" radiofrequency current pulse to minimize the possibility of late recurrence of accessory pathway conduction.

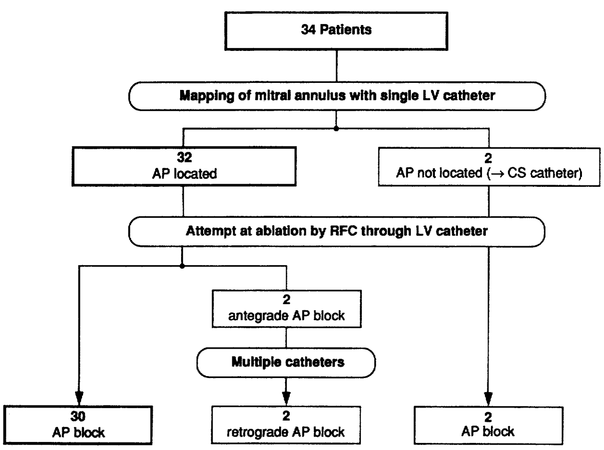

FIGURE 5. *Flow chart illustrating outcome of the single-catheter approach to ablation of accessory pathways in 34 patients. AP, accessory pathway; CS, coronary sinus; LV, left ventricle; RFC, radiofrequency current.*

Approximately 30 minutes after the last radiofrequency current pulse, a standard 6F quadripolar catheter was introduced via the femoral sheath into the right ventricle to ascertain absence of retrograde accessory pathway conduction by right ventricular stimulation using the extrastimulus technique. Retrograde conduction across the atrioventricular node was assumed if increasing prematurity of the extrastimulus caused a progressive increase of the stimulus-atrium interval recorded from the left ventricular catheter. The stimulation catheter was then withdrawn and positioned in the right atrium for stimulation at increasing rates to exclude the presence of a second accessory pathway capable of antegrade conduction.

The patients were transferred to the regular patient ward for 24-hour electrocardiographic monitoring, determination of creatine kinase values, and two-dimensional echocardiography.

After hospital discharge, the patients were seen in the outpatient clinic after 1 and 3 months and every 6 months thereafter. At each visit, the patient's clinical course was assessed, a physical examination was performed, and a surface electrocardiogram and two-dimensional echocardiogram were recorded.

Statistics

Data are presented as mean±1 SD where appropriate. In cases of a non-Gaussian distribution of measured parameters, the median value is given instead of the mean. Comparisons between continuous variables were analyzed using Student's two-tailed t test for unpaired samples or the Mann-Whitney U test. A probability of less than 5% was considered statistically significant.

Results

The 34 patients of the single-catheter group and the 35 patients of the multiple-catheter group did not differ regarding age, sex, location of accessory pathways, and type of arrhythmia. A single left-sided free-wall accessory pathway was found in all. The anatomical distribution of pathway sites in the single-catheter group of patients is shown in Figure 4. The single-catheter approach to ablate accessory pathway conduction was wholly successful in 30 of 34 patients (88%). Accessory pathway potentials with an atrium-accessory pathway interval of 22±7 msec; a median accessory pathway-delta wave interval of 0 msec (range, 0–20 msec), and an accessory pathway-ventricle interval of 16±5 msec could be recorded with the left ventricular catheter in 32 single-catheter-group patients; in the two other patients (patients 3 and 9), pathway sites were determined using a coronary sinus mapping catheter (Figure 5). Radiofrequency current application through the left ventricular catheter abolished both antegrade and retrograde accessory pathway conduction in 32 patients (including patients 3 and 9) in a single ablation session. Permanent conduction block in the accessory pathway occurred 3.0±2.0 seconds after the successful radiofrequency current

pulse. Loss of preexcitation was always associated with the disappearance of the accessory pathway potential.

In two patients (patients 16 and 17), the pathway could be located from the left ventricle by using the single-catheter approach, but radiofrequency current application resulted only in antegrade accessory pathway conduction block. In patient 16, this was noticed during control stimulation after the seventh (presumed successful) radiofrequency pulse; retrograde accessory pathway conduction was subsequently abolished after 31 radiofrequency pulses by using the multiple-catheter approach. In patient 17, retrograde conduction through the pathway persisted at the end of an initial ablation session that had required 21 current applications for antegrade accessory pathway block. The patient experienced recurrent episodes of arrhythmia and underwent a repeat session 3 months later with multiple catheters during which retrograde conduction block was achieved.

During the single-catheter ablation sessions, a median of four (range, 1–21) radiofrequency pulses were applied (Table 2). They had a mean electrical power of 24.9±4.3 W and lasted for 22.3±4.6 seconds. Cumulative electrical energy delivered per session ranged from 398 to 14,098 J, with a median value of 2,000 J. Procedure duration was 2.0±1.1 hours and radiation exposure time for catheter positioning averaged 22.8±20.4 minutes (median, 17.3 minutes).

In an attempt to assess the influence of the investigators' growing experience with catheter ablation, a comparison with the single-catheter patients was performed separately for the 20 multiple-catheter patients who underwent the procedure before the start of the single-catheter project and for the 15 in whom multiple catheters were used because minimally preexcited QRS morphology did not allow an unequivocal determination of a left free-wall pathway location (compare with Table 2). Statistically significant differences were found for the first 20 multiple-catheter patients in the number of radiofrequency pulses, session duration, and, consequently, radiation exposure time (a median of 7, $p<0.02$; 4.6±2.0 hours, $p<0.001$; and 53.7±38.0 minutes, $p<0.001$, respectively). In the 15 patients in whom the multiple-catheter approach was used from the beginning because of minimal preexcitation, the number of radiofrequency pulses in particular, session duration and radiation exposure time were again significantly increased (a median of 15, 4.4±2.1 hours and 56.2±42.4 minutes, respectively; for all parameters $p<0.001$ versus the single-catheter approach). There were no acute complications related to either type of ablation procedure.

Except for patient 17, no patient who underwent the single-catheter approach for ablation of an accessory pathway experienced recurrences of their arrhythmia during 6.4±3.8 months of follow-up. All patients were without antiarrhythmic medication and free of symptoms. Follow-up electrocardiograms and echocardiograms were normal. A postablation electrophysiological study performed in seven patients disclosed no evidence of accessory pathway conduction; postablation coronary angiography in nine patients revealed grossly normal coronary artery morphology.

Discussion

Catheter ablation with the use of radiofrequency current is increasingly being attempted in patients with accessory atrioventricular pathways. Various centers have recently reported preliminary success rates between 67 and 100%, with acute complications occurring in 0–7% of patients.[7,8,19–23] If these results can be maintained during long-term follow-up, the technique may become the treatment of first choice for symptomatic patients with arrhythmias mediated by an accessory pathway and, for selected patients, as a prophylaxis against life-threatening arrhythmias. In contrast with cardiac surgery, which is as effective although associated with a low mortality and morbidity in some centers, patient acceptance is markedly higher and medical care costs are significantly reduced.[24]

Catheter ablation procedures, including the radiofrequency current approach, may take long periods of time and are associated (because of repeated attempts at correct catheter placement) with a significant radiation exposure of both the patient and the investigator. A procedure using multiple catheters to locate the accessory pathway and to determine electrophysiological parameters may last for several hours, with corresponding radiation exposure times in excess of 2 hours. These long investigation times limit the widespread use of the technique; they may be hazardous to the health of patients and physicians because of the extended exposure to radiation.[25] Moreover, the prolonged use of the catheter laboratory for a single procedure as well as the continued presence of individual investigators for longer periods of time may not be possible at all centers. Physical and psychological exhaustion of the team of physicians may increase the risk of preventable side effects.

Single-Catheter Approach

The present study demonstrates that radiofrequency current catheter ablation of left-sided accessory pathways capable of consistent antegrade conduction can be achieved with a single catheter placed inside the left ventricle close to the mitral annulus. The approach is safe and associated with an efficacy close to 90%. Overall procedure duration, including a 30-minute delay before the final electrophysiological assessment of atrioventricular and ventriculoatrial conduction, was reduced to an average of 2 hours, with a corresponding decrease of the mean radiation exposure time of less than 25 minutes.

The reduction in procedure duration results primarily from the fact that accessory pathway localization is done with the same catheter that is used for ablation and secondarily from dispensing with any preablation electrophysiological assessment. The multiple-catheter approach that was used exclusively before this study was begun lasted for approximately

Table 2. Ablation Session Data in 69 Patients With Overt Left-Sided Free-Wall Accessory Pathways

		RFC applications					
Pt No.	Proc	#	Power (W) Mean	Duration (sec) Mean	Energy (J) Cumulative	Session dur (hr)	Rad exp (min)
1	SC	2	31.5	20.0	1,261	1.25	1.6
2	SC	21	27.1	24.8	14,098	3.25	40.0
3	SC	12	29.6	27.8	9,850	2.50	32.2
4	SC	3	30.3	30.0	2,720	1.50	17.1
5	SC	9	29.8	36.6	9,830	2.00	27.9
6	SC	4	28.8	20.0	2,304	1.25	3.8
7	SC	4	30.4	20.0	2,430	1.00	8.6
8	SC	4	20.1	27.5	2,072	1.00	8.0
9	SC	12	24.4	19.3	6,049	3.67	98.2
10	SC	3	26.1	20.0	1,569	1.00	21.1
11	SC	4	28.3	22.5	2,544	2.50	25.6
12	SC	3	22.9	20.0	1,483	2.25	13.2
13	SC	2	30.5	25.0	1,523	1.00	18.9
14	SC	3	20.8	12.7	803	3.50	33.5
15	SC	2	26.9	25.0	1,348	3.00	19.1
16	SC	7	30.0	25.7	5,394	6.25	60.6
	MC	31	20.0	23.0	14,780		
17	SC	21	23.9	25.5	8,569	3.50	64.1
	MC	53	22.9	20.2	24,583	7.50	81.1
18	SC	7	25.7	19.3	3,503	2.33	48.3
19	SC	5	27.5	24.0	3,301	1.50	18.6
20	SC	9	19.7	16.1	2,916	2.50	36.2
21	SC	6	28.5	28.3	4,907	2.00	33.0
22	SC	3	24.2	23.3	1,697	1.00	4.4
23	SC	3	24.8	23.3	1,732	1.50	12.2
24	SC	4	24.1	20.0	1,927	1.75	9.9
25	SC	7	21.7	18.4	2,865	1.50	16.0
26	SC	2	19.8	25.0	991	0.75	2.6
27	SC	1	19.9	20.0	398	1.25	5.7
28	SC	3	11.7	17.0	562	1.50	11.6
29	SC	4	25.3	17.0	1,680	1.00	8.0
30	SC	2	18.8	25.0	930	1.75	17.5
31	SC	2	24.2	20.0	969	1.50	13.2
32	SC	6	23.9	18.3	2,674	1.67	18.7
33	SC	2	22.6	19.5	879	2.00	12.6
34	SC	2	24.4	20.0	974	1.00	12.5
35*	MC	7	4.9	12.9	454	2.50	...
	MC	7	23.3	19.3	3,120	2.25	21.5
36*	MC	9	3.2	20.9	603	3.25	...
37*	MC	15	5.1	20.7	1,568	5.50	...
38*	MC	2	6.6	20.0	264	4.25	...
39*	MC	14	8.2	18.4	1,961	7.25	...
40*	MC	8	5.8	20.0	931	4.75	...
41*	MC	10	8.9	18.0	1,296	5.00	65.5
	MC	8	7.1	20.0	1,136	3.75	64.4
42*	MC	7	4.6	19.1	612	4.25	34.4
43*	MC	1	21.5	20.0	430	3.75	12.3
44*	MC	18	21.4	18.2	6,846	6.75	94.3
	MC	20	32.3	21.6	13,029	8.00	100.5
45*	MC	1	18.0	20.0	360	2.75	13.7
46*	MC	26	27.8	19.3	13,594	10.50	148.2
47*	MC	25	24.4	22.1	13,055	7.00	105.0
	MC	13	21.5	19.2	5,260	3.50	52.9

TABLE 2. Ablation Session Data in 69 Patients With Overt Left-Sided Free-Wall Accessory Pathways (continued)

		RFC applications					
Pt No.	Proc	#	Power (W) Mean	Duration (sec) Mean	Energy (J) Cumulative	Session dur (hr)	Rad exp (min)
	MC	23	25.4	21.4	12,142	4.50	77.1
48*	MC	3	23.7	19.2	1,360	3.50	27.1
49*	MC	5	24.7	24.8	3,080	4.00	42.9
50*	MC	2	27.9	20.0	1,116	3.50	27.3
51*	MC	5	29.0	18.4	2,674	3.50	25.3
52*	MC	2	30.4	20.0	1,217	3.00	17.4
53*	MC	4	28.7	17.5	1,999	5.00	70.7
54*	MC	3	27.0	14.3	1,204	3.25	20.6
55	MC	12	25.1	23.1	6,902	3.75	59.0
56	MC	39	22.4	23.1	19,394	5.75	120.0
57	MC	8	28.9	17.8	4,106	3.00	34.8
58	MC	23	17.2	24.5	9,690	5.75	63.9
59	MC	3	26.1	20.0	1,563	1.00	17.2
60	MC	21	28.0	19.5	7,114	4.00	81.6
61	MC	47	24.7	23.1	26,405	7.75	66.8
62	MC	3	27.3	20.0	1,639	1.25	17.7
63	MC	35	23.1	30.2	24,120	6.50	131.6
64	MC	32	16.9	27.0	14,013	5.25	117.8
	MC	11	25.0	22.7	6,231	3.75	42.8
65	MC	34	23.4	26.5	20,430	8.00	8.2
66	MC	2	19.6	25.0	983	3.33	19.0
67	MC	3	24.3	20.0	1,455	2.00	10.0
68	MC	2	16.5	12.5	447	4.50	28.3
69	MC	17	21.7	22.8	8,240	5.50	63.5

*Studied prior to single-catheter project.

Patient numbers for the single-catheter (SC) group correspond to those in Table 1. AP, accessory pathway; dur, duration; hr, hours; J, joules; MC, multiple-catheter; min, minutes; Proc, procedure; Pt, patient; Rad exp, radiation exposure time; RFC, radiofrequency current; sec, seconds; W, watts.

4.5 hours, although the median number of radiofrequency current pulses was only slightly higher than in the single-catheter procedures (the latter difference may be related to increased experience of the investigators). Patients with overt left-sided accessory pathways subjected to the multiple-catheter approach while the single-catheter project was going on represent a selected group of patients who lack an unequivocal delta wave pattern. In them, procedure duration was the same as in the initial unselected multiple-catheter patients, but a significantly larger number of radiofrequency current pulses (median, 15) was necessary for accessory pathway ablation. This may be attributed to the fact that transient accessory pathway block was repeatedly encountered in several of these patients and that cardiac morphology rendered the access to the ventricular aspect of the mitral annulus more difficult in others (patients 61 and 65). The single-catheter approach has an added advantage in that anterolateral accessory pathways that are frequently inaccessible with a coronary sinus catheter[18] can be precisely located.

Prerequisites for Single-Catheter Approach

The single-catheter approach to the ablation of an overt left-sided accessory pathway may be attempted on the premises of several conditions: 1) The delta wave pattern in the 12-lead electrocardiogram must allow the determination of the location of the accessory pathway at the left free wall, 2) placement of the ablation catheter within the left ventricle high against the annulus is verified by the recording through the left ventricular catheter of an atrial potential that is at least 25% in amplitude of the ventricular potential, 3) further evidence of a correct placement of the ablation catheter is gained from the typical movement of the catheter in concert with the mitral annulus, as it is known from a coronary sinus catheter, and 4) on the left ventricular electrogram an accessory pathway activation potential is recorded that follows the atrial potential by 30 msec or less, precedes or coincides with the onset of the delta wave, and precedes the ventricular potential by at least 10 msec; this criterion is the result of the analysis of local electrograms obtained during previous multi-catheter procedures through the coronary sinus and the left ventricular catheter from sites of successful interruption of accessory pathway conduction; it has proved to be an excellent marker for the optimal ablation site.[15]

Limitations of Single-Catheter Approach

First, the use of a single catheter in the left ventricle for precise accessory pathway localization requires experience in the manipulation of this catheter along the mitral annulus without the guidance of a coronary sinus catheter. This experience must be gained with the conventional technique by using a coronary sinus catheter before the single-catheter technique is attempted. Second, the very nature of an accessory pathway activation potential cannot be verified with just a single catheter in the left ventricle. To this end, various stimulation techniques are needed.[9,18] However, in analogy to His bundle potentials, an accessory pathway potential can be assumed if this potential is distinguished from both a local atrial and ventricular potential and precedes or coincides with the onset of the delta wave. Moreover, retrospective analysis of local electrocardiograms at sites of a successful accessory pathway ablation favor the assumption of an accessory pathway origin if the interruption of pathway conduction (loss of the delta wave) is associated with the disappearance of this potential.

In cases of failure to precisely locate the accessory pathway or if supraventricular tachycardia of the atrial, atrioventricular nodal reentrant, or even atrioventricular type mediated by an additional concealed pathway is inducible at the end of the procedure, the introduction of further catheters may become necessary. In the present study, sustained supraventricular tachycardia was not induced after ablation, but an inadequate left ventricular catheter map was encountered in two patients (7%). A conversion to the multi-catheter approach at this point may not necessarily prolong the procedure as compared with a multi-catheter approach intended from the start, but it has the disadvantage of a venous puncture under full heparinization. Therefore, puncture of the subclavian vein for introduction of the coronary sinus catheter should be avoided and the left brachial or the right internal jugular venous route used instead.

In some patients, retrograde conduction either across the same or another accessory pathway or across the specific conduction system may persist, even if supraventricular tachycardia cannot be induced at the end of the ablation procedure. Retrograde conduction across the His bundle–atrioventricular node axis can be assumed if ventriculoatrial conduction time gradually increases with increasing prematurity of ventricular extrastimuli, and no further evaluation is necessary. In all other situations, the presence of retrograde accessory pathway conduction must be suspected and further electrophysiological study performed.

Conclusions

The single-catheter approach to the ablation of overt left-sided free-wall accessory pathways is based on the authors' experience gained from radiofrequency current ablation by using the conventional approach with multiple catheters.[14] The technique is highly effective, requiring a retreat to the multi-catheter approach in only a few patients. It significantly reduces procedure duration and, consequently, radiation exposure, and may thus further increase the attractiveness of radiofrequency current catheter ablation in patients with Wolff-Parkinson-White syndrome. Further studies are needed to establish whether the single-catheter approach can be expanded to the ablation of overt free-wall accessory pathways on the right side of the heart.

Acknowledgments

The authors would like to thank Bettina Voigt, Helga Gustke, Manfred Geiger, MD, Jürgen Siebels, MD, and Wolfgang Duckeck, MD, for their assistance in the conduction of this study.

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KEY WORDS • electrocoagulation • Wolff-Parkinson-White syndrome • tachycardia, supraventricular • atrial fibrillation