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RADIOFREQUENCY CATHETER ABLATION OF ACCESSORY PATHWAYS AND MODIFICATION OF ATRIOVENTRICULAR NODE IN CHILDREN AND ADOLESCENTS*

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Catheter ablation of an accessory pathway and atrioventricular node modification using 550 kHz radiofrequency was attempted in 23 children and adolescents between five and 19 years of age (mean = 15.7 years). Fifteen children had accessory-pathway-mediated tachycardia and eight had atrioventricular node reentrant tachycardia.

Accessory pathways were present in ten children. Two patients had associated congenital heart disease. Symptoms included disabling palpitations and episodes of syncope. Ablation was attempted from the right and left sides of the heart. Single-catheter technique was used in seven patients. Eleven of the 15 patients with accessory pathways were treated completely. Two patients had recurrences, and one of them died after the arrhythmia surgery. There were two failures. Two patients with incomplete interruption of the accessory pathways were followed up clinically. There were three cases with temporary systemic embolization and one with severe pain related to radiofrequency energy application.

Atrioventricular node modification was done by fast-pathway ablation in six, and by slow-pathway ablation in two patients. Two patients with fast-pathway ablation had recurrences of clinical arrhythmia, and one of them underwent a successful second session. There were no complications associated with the procedure in this group of patients.

Radiofrequency catheter application was initially successful in 21 (84%) out of 25 procedures, and ultimately curative in 16 (69%) out of 23 patients. There were some serious complications which resolved in the immediate post-procedure period. Radiofrequency catheter ablation appears to be a safe and successful method for the management of supraventricular tachycardia secondary to accessory pathways or atrioventricular node reentrant tachycardia in children and adolescents. *Key words: radiofrequency catheter ablation, supraventricular tachycardia, children.*

Supraventricular tachycardia is the most common sustained arrhythmia in children, and is usually associated with accessory-pathway-mediated tachycardia or atrioventricular (AV) node reentrant tachycardia[1]. These tachycardias are associated with significant symptoms, and medical therapy may be ineffective in some cases. Catheter ablation with high-voltage, direct-current shock has been used for ablation of accessory pathways and modification of the AV node in

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children[2-5]. However, direct-current shock ablation results in explosive gas formation and generation of a shock wave. Since 1987, transcatheter application of radiofrequency energy has been used in adults to manage these arrhythmias[6,7]. The absence of hazardous effects of direct-current shock makes the radiofrequency catheter ablation technique particularly encouraging for use in children. There have been a few reports of the use of this technique in children[8-12]. This report describes our initial experience with the use of radiofrequency catheter ablation in the management of children and adolescents with sustained symptomatic accessory-pathway-mediated tachyçardia and AV node reentrant tachycardia.

Material and Methods

Patient Selection : All patients were referred to our center (O.L.V. Hospital Cardiovascular Center, Arrhythmia Unit) for evaluation and management of frequent supraventricular tachycardia episodes, After an initial evaluation that included history, physical examination, electrocardiogram (ECG) and in some cases 24-hour ambulatory ECG, exercise testing, and echocardiography, eight patients underwent a standard electrophysiologic study; the mechanism of tachycardia was confirmed in these cases before the ablation procedure. Two patients had Ebstein's anomaly of the tricuspid valve, and one of them had been operated on for a previous right-lateral accessory pathway.

Patients who would have otherwise been incurable by antiarrhythmia drugs became candidates for radiofrequency catheter ablation. The criteria were as follows:

1. An accessory pathway or AV node reentrant tachycardia was present in a patient with frequent symptomatic episodes of supraventricular tachycardia which occurred despite treatment with several antiarrhythmic drugs.
2. Antiarrhythmic drugs partially or completely controlled the supraventricular tachycardia but were associated with side effects.
3. The patient or parents did not want to use antiarryhythmic drugs because of the possibility of long-term drug dependency. Twenty-three patients met these criteria and underwent the catheter ablation procedure. The patients or their parents gave written consent for the catheter ablation intervention.

RF Catheter Ablation Technique

Radiofrequency energy was supplied by a radiofrequency energy generator system (Hat 200, Dr. Osypka GMBH, Germany) to obtain a continuous unmodulated current at 550 kHz. Energy was applied between the distal pole of a 7F steerable quadripolar electrode catheter with a 4 mm distal electrode (Mansfield Webster, USA), and a large surface area skin electrode was placed over the left scapula. All patients received anticoagulant therapy using 100 U/kg (maximum 5000 U) of intravenous heparin.

Accessory Pathway Ablation : The accessory pathway location was classified according to the electrophysiologic study, the pattern of the delta wave in sinus rhythm and retrograde atrial activation polarity during a supraventricular tachycardia attack. In patients with left-sided accessory pathways, the ablation catheter was introduced from the femoral artery retrograde to the left ventricle and positioned against the AV ring. When this approach failed, the left atrial approach was used. In patients with a posteroseptal accessory pathway, the ablation catheter was advanced from the right femoral vein and positioned around the coronary sinus ostium. In patients with a right lateral accessory pathway, the ablation catheter was inserted from the right femoral vein and positioned in the right atrium.

The ablation catheter was positioned to record both atrial and ventricular electrograms and the shortest AV interval during the sinus rhythm in patients with manifest Wolff-Parkinson-White syndrome (WPW), and the shortest ventriculoatrial interval during orthodromic supraventricular tachycardia or during ventricular pacing in patients with a concealed accessory pathway. We tried to obtain accessory pathway potentials and continuous electrical activity before the ablation. Radiofrequency energy was applied at a power output of 30-40 W for 30 seconds. After the ablation, ventricular stimulation was then performed to evaluate the absence of ventriculo atrial conduction. Also, atrial stimulation was carried out in order to check whether tachycardia was still inducible.

AV Nodal Modification : A 7F steerable quadripolar catheter was advanced to record bipolar electrograms in the vicinity of the AV node prior to radiofrequency application. First the catheter was placed across the tricuspid annulus to record the His bundle potential (HBP) and was slowly withdrawn so that a larger atrial deflection was recorded. The target sites have an atrial/ventricular ratio greater than one and a small (< 100 mV) or absent HBP. Radiofrequency energy was used until the atrium-to-His interval was prolonged by approximately 50 percent when a non-conducting P-wave was seen. Ablation of the slow AV nodal pathway occurred when the RFA catheter was placed superiorly to the site of recording of a HBP, while ablation of the fast AV nodal pathway was seen when locating the catheter inferior to the His.

Results

Twenty-five procedures were performed in 23 patients between five and 19 years of age (mean = 15.7, median = 16 years, Tables I, II). Fifteen patients had an accessory pathway, and eight had AV node reentrant tachycardia. Radiofrequency catheter ablation was initially successful in 21 (84%) of the 25 procedures and ultimately curative in 16 (69%) of 23 patients.

Table I: Clinical, Electrophysiologic and Radiofrequency Ablation Data of Patients with Accessory Pathway-Mediated Tachycardia

						RFA		Shock			Follow-up			
Patient	Sex	Age (Years)	Symptoms (Years)	Drug	Diagnosis	RET (Min.)	PD (Min.)	N	Power (Watts)	Complications	EPS	Drug	Months	Results
1.	F	15	P (2)	S	LPS, AS, LL Manifest	134	360	–	–	None	–	S	8	Sæ
2.	M	16	P, Pre (2)	V, S	Para His# Manifest	–	–	24	–	None	–	–	1	S
3.	M	5	P (5)	D, P	LL*@ Pro	33 Concealed	70	6	–	None	+	–	–	R
4.	M	16	P (7)	D, S, A	LL* Concealed	67	240	38	–	Embolization	+	–	4	S
5.*	F	18	P, Pre (14)	A, Pr Pro	LL Manifest	19.4	45	2	40	Embolization	–	–	–	S
6.*	M	17	Pro P, Pre	Pro	ParaHis Manifest	14	45	1	25	None	–	–	–	S
7.	M	15	P (1)	S	LL Concealed	65.6	160	30	30	None	–	–	1	Sæ
8.*	M	15	P (2)	S	LL Manifest	89.2	210	60	23	None	–	S	1	F
9.*	M	15	P (2)	None	LL Manifest	24.4	55	10	32	Embolization	–	–	–	S
10.	F	15	P (1)	Pro	LPS, LP Concealed	26.5	105	6	30	None	–	–	1	S
11.	F	15	P (1)	None	LL Manifest	2.7	30	2	35	None	–	–	2	S
12.	F	19	P (6)	Pr, Pro A	RL Manifest	6.4	15	2	35	None	–	–	1	R
13.*	M	16	P* (3)	None	AS Manifest	86	175	–	–	Pain	–	S	–	F
14.*	M	18	P, Pre (2)	None	LL Manifest	9.6	30	6	35	None	–	–	–	S
15.	M	15	P (2)	S	LL Concealed	18.1	40	6	35	None	–	–	–	S

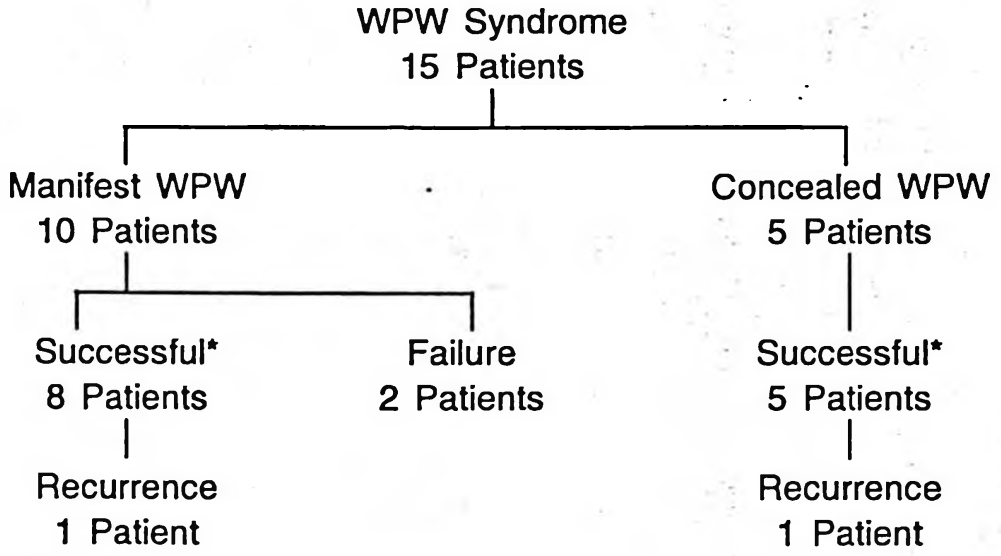
RFA: radiofrequency application, RET: radiation exposure time, PD: procedure duration, Min: minutes, N: number of shocks, EPS: electrophysiologic study, F: female, M: male, P: palpitation, Pre: presyncope, S: sotalol, V: verapamil, A: amiodarone, Pr: propranolol, Pro: propafenone, D: digoxin, LPS: left posteroseptal, AS: anteroseptal, LL: left-lateral, #: associated with AV node reentrant tachycardia, *: Ebstein's anomaly of tricuspid valve, @: second ablation session, LP: left posterior, RL: right-lateral, S: successful, æ: partially successful, F: failure, R: recurrence.

Table II: Clinical, Electrophysiologic and Radiofrequency Ablation Data of Patients with AV-Node Reentrant Tachycardia

						RFA		Shock			Follow-up				
Patient	Sex	Age (Years)	Symptoms (Years)	Previous Intervention	Drug	RET (Min.)	PD (Min.)	N	Power (watts)	Ablation Site	Complications	EPS	Drug	Months	Results
1.	F	18	P, Pre (6)	EPS	Pr	20.6	75	3	–	F PW	None	–	–	7	No arrhythmia
2.	M	13	Syn (3)	–	Pr	6.8	45	2	30	S PW	None	–	–	6	No arrhythmia
3.	F	15	P (4)	EPS	D, S	–	–	1	32	S PW	None	–	–	7	No arrhythmia
4.	F	18	P, Pre (2)	–	S	20	75	3	–	F PW	None	–	–	3	No arrhythmia
5.	F	17	P (3)	EPS	D, Pr	–	–	3	30	F PW	None	–	–	5	Recurrence
6.	M	18	P (5)	–	–	–	45	3	31	F PW	None	–	–	2	No arrhythmin
7.	F	17	P	EPS	S, Pr	16.3	65	9	30	F PW	None	–	–	3	Recurrence
8.	F	18	P (1)	–	S	32	90	26	32	F PW	None	–	–	2	No arrhythmin

Syn: syncope, F PW: fast-pathway, S PW: slow-pathway, #: second ablation session, RFA: radiofrequency application, RET: radiation exposure time, PD: procedure duration, N: number of shocks, EPS: electrophysiologic study, F: female, M: male, P: palpitation, Pre: pesyncope, Pr: propranolol, D: digoxin, S: sotalol.

Accessory pathway ablation (patients 1-15, Table I). Fifteen children and adolescents (11 boys, 4 girls) between five and 19 years of age (mean 15 years) underwent radiofrequency catheter ablation of accessory pathways. Wolff-Parkinson-White (WPW) syndrome was present in 10 children, while the other five were found to have a concealed accessory pathway capable of only retrograde conduction. All procedures required a median of 10 applications of radiofrequency energy (range 1 to 38) at an application output power of 25 to 40 W (mean = 33 W). The mean duration of procedures was 100 min (range 15 to 360 min) and the mean radiation exposure time 35 min (range 2.7 to 134 min). One patient had two, and one patient had three accessory pathways. One patient also had AV-node reentrant tachycardia. The single catheter technique was used in five patients with left lateral AP, and one patient with parahisian AP with manifest WPW. Thirteen of the 15 procedures were successful (Fig. 1). In seven successful procedures in patients with manifest preexcitation, the delta wave disappeared. Immediate restudy showed the absence of preexcitation with atrial stimulation and the absence of ventriculoatrial conduction.



*: one case partially successful.

Fig. 1: RF ablation results in patients with WPW syndrome.

Eleven patients had absent ventriculoatrial conduction, and supraventricular tachycardia was no longer inducible. There were two partially successful procedures and two failures. The single catheter technique failed in these patients. Three patients developed signs of systemic embolization and one patient experienced severe pain during the radiofrequency catheter ablation. The patients with systemic embolization recovered completely in the immediate post-ablation period. During follow-up, two patients had recurrences and one of them died

immediately following the successful surgical division of the left lateral accessory pathway. Follow-up electrophysiologic studies were performed in two patients who had successful procedures, and confirmed a recurrence in one of them. Ten patients were asymptomatic without medication after a follow-up interval of one to eight months. Six of the ten successfully treated patients who had preexcitation before the procedure had no preexcitation on follow-up ECG.

AV node modification (patients 16-23, Table II). Eight children and adolescents (two boys, six girls) between 13 and 18 years of age (mean 16 years) underwent radiofrequency catheter modification of the AV node. Four of the eight patients had electrophysiologic studies done before catheter modification of the AV node, showing anterograde dual AV node conduction curves in all of them. Six patients had fast-pathway and two slow-pathway ablation. These procedures required a median of three applications of radiofrequency energy (range 1-26) at an application power output of 30 to 32 W (mean = 30 W). The mean duration of procedures was 65 min (range 45-90 min) and the mean radiation exposure time was 19 min (range 6.8-32 min). There were no complications. Immediate testing after the procedure showed the absence of ventriculoatrial conduction, and this arrhythmia was no longer inducible. PR and AH intervals were prolonged in all patients who had fast-pathway ablation. During follow-up of these patients, two of them had recurrences, and the PR interval was shortened in these patients. One of them was managed with a second ablation session. Seven patients were asymptomatic without medication after a follow-up period of two to seven months (mean = 4.4 months).

Discussion

After initial procedures of catheter ablation of the AV junction in adults using direct-current shock, the same technique has been extended for use in patients with all types of supraventricular tachycardia. There is now wide experience with direct-current catheter ablation of the posteroseptal accessory pathway and more recently of accessory pathways in other locations. Direct-current shock has also been used to modify the AV node in patients with AV-node reentrant tachycardia. However, experience with direct-current shock ablation in children is limited[2-5]. Direct-current shocks of 50 to 250 J were used by Gillette et al.[5] for ablation of ectopic atrial tachycardia foci in four children, with success in two. Smith et al.[4] used shocks of 25 to 300 J delivered to the mouth of the coronary sinus in four children with a permanent form of junctional reciprocating tachycardia, achieving permanent ablation of the retrograde accessory pathway in only one. Bromberg et al.[3] reported on six children, eight to 18 years in age, with an accessory pathway who had undergone direct-current catheter ablation procedures. Only two patients were without signs of accessory pathway function

on follow-up, and three patients underwent surgical division of the accessory pathway. AV node modification using direct-current shock catheter ablation has not been reported in children. Also, the direct-current approach has many disadvantages, such as apparent lack of energy titration and the need for general anesthesia.

The application of radiofrequency energy is not associated with barotrauma. Its physiological efficacy results from resistive heating of cardiac tissue, and the lesions are found to be rather circumscript and small. Radiofrequency energy application can be controlled on the anatomical substrate and requires no general anesthesia[6,7]. Radiofrequency energy has now been applied successfully and safely in adults and children for AV-node modification of AV-node, reentrant tachycardia, and ablation accessory pathways located in various positions. Saul et al.[12] described the initial successful results in children with accessory-pathway-mediated tachycardias. Dick et al.[13] reported the success rate of radiofrequency catheter ablation of accessory pathways as 74 percent, and this rate was even higher in the left-sided accessory pathway in 10 of 13 children after a follow-up interval 1.25 to seven months. They also described successful modification of the AV node in children with AV-node reentrant tachycardia. Another study, performed by Schluter and Kuck[9], showed the effectiveness of the single-catheter technique in three children with left-sided accessory pathways. They also reported complete ablation of accessory pathways in various positions in 10 of 11 children in the same study.

In our study, complete ablation was achieved in nine of 15 children with accessory pathways. Two patients with partially successful results were followed without symptoms. Totally symptom-free lives were obtained by eleven patients.

Although AV-nodal reentry tachycardia is not as common in children as adults, it may cause severe problems in childhood. Slow-pathway ablation is the treatment of choice because of the low risk of permanent AV block. However, the technique for this approach is not easy, and the duration of the procedure and the number of radiofrequency applications needed is higher than in fast-pathway ablation[13]. Also, titration of radiofrequency energy and increased experience prevent inadvertent AV block. Van Hare et al.[8] reported high success and low complication rates with fast-pathway ablation. In one collaborative study the results were similar in success and complication rates to those with adults[11]. In our study group we observed two recurrences in the fast-pathway ablation group without AV conduction block. These results were consistent with previous reports. Fast-pathway ablation may be done by experienced centers with no complications and a reasonably low recurrence rate.

In conclusion, radiofrequency catheter ablation is becoming an acceptable and preferred method for the treatment of supraventricular tachycardia in children. The low risk of complications and high success rate compared to arrhythmia surgery and direct-current ablation demonstrate its safety and efficacy.

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