

## Pediatric Radiofrequency Catheter Ablation: Results of Initial 100 Consecutive Cases Including Congenital Heart Anomalies

Radiofrequency catheter ablation (RFCA) has recently become a management option for pediatric tachycardia. We reviewed the records of a total of 100 patients (aged 10 months to 19 yr) who had undergone RFCA, from March 2000 to June 2004. Types of arrhythmia (age, acute success rate) were as follows: atrioventricular reentrant tachycardia (AVRT,  $9.0 \pm 3.7$  yr, 66/67), atrioventricular nodal reentrant tachycardia (AVNRT,  $13 \pm 2.5$  yr, 16/16), ectopic atrial tachycardia ( $6.4 \pm 3.3$  yr, 5/5), junctional ectopic tachycardia (10 month, 1/1), ventricular tachycardia ( $12 \pm 4.9$  yr, 6/6), post-surgical intraatrial reentrant tachycardia ( $15.6 \pm 4.1$  yr, 2/3), twin node tachycardia (4 yr, 0/1), and His bundle ablation (9 yr, 1/1). The age of AVNRT was older than that of AVRT ( $p=0.002$ ). Associated cardiac disease was detected in 17 patients, including 6 univentricular patients, and 3 Ebstein's anomaly patients. RFCA for multiple accessory pathways required longer fluoroscopic times than did the single accessory pathway ( $53.9 \pm 4.8$  vs.  $36.2 \pm 24.1$  min;  $p=0.03$ ), and was associated with a higher recurrence rate (3/9 vs. 3/53;  $p=0.03$ ). Regardless of the presence or absence of cardiac diseases, the overall acute success rate was 97% without major complications, the recurrence rate was 8.2%, and the final success rate was 97%. This experience confirmed the efficacy and safety of RFCA in the management of tachycardia in children.

Key Words : Tachycardia; Catheter Ablation; Heart Defects, Congenital

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## INTRODUCTION

Since its initial clinical application in pediatric patients in 1990, radiofrequency catheter ablation (RFCA) has become a viable option for the management of tachycardia in children (1-5). In 2000, we began to use RFCA in the treatment of children with tachycardia, and after our initial experience of 100 consecutive RFCA in children, we performed a retrospective study to elucidate the safety and efficacy of the procedure. We also assessed the influence of congenital heart malformations and surgery on the efficacy and safety of RFCA.

## MATERIALS AND METHODS

### Patients

From March 2000 to June 2004, we conducted electrophysiological studies (EPS) on 144 patients in the Pediatrics department of our institution. Prior to EPS, we planned concomitant RFCA for the treatment of symptomatic tachycardia in 109 of these patients. Among these 109 patients, RFCA was excluded as an option for 6 patients, as their parents re-

fused the procedure due to its relatively high complication rate. These 6 cases included: one junctional ectopic tachycardia with Ebstein anomaly, one concealed nodo-fascicular tract with corrected transposition of great arteries, one multifocal atrial tachycardia, one midseptal accessory pathway (AP), one para-Hissian AP, and one patient whose AP had been rendered inactive due to mechanical trauma. We attempted RFCA in 103 patients, and 3 patients who were 20 yr of age or older were excluded from this study. We then conducted a retrospective evaluation of the 100 consecutive patients who had undergone RFCA when younger than 20 yr of age.

### Procedures

EPS and ablation were performed under conscious sedation, using midazolam if the patient was younger than 13 yr of age. Three of the patients required respiratory support with concomitant endotracheal intubation, as one patient exhibited persistent tachycardia with impending cardiogenic shock, and the other two patients exhibited upper airway obstructions due to adenoid and tonsillar hypertrophy. In most of the patients, two right femoral vein sheaths, two left femoral vein sheaths, and one left femoral arterial line were installed.

EP catheters were introduced into the high right atrium, the His bundle area, the right ventricle, and the coronary sinus. High right atrial catheter was later replaced by an ablation catheter. All studies were performed guided by biplane fluoroscopy. Angiographies were taken prior to ablation if the patient had a congenital heart disease or ectopic tachycardia. Electrode catheter size varied from 5 F to 7 F (St. Jude Medical, Daig Division, Minnetonka, MN, U.S.A.) according to the individual patient. After the diagnostic EP study, mapping and ablation using an ablation catheter (Boston Scientific EP Technology, San Jose, CA, U.S.A.) was performed. All induced tachycardias were found to be identical to clinical tachycardia. When appropriate sites had been identified, radiofrequency energy was delivered by a temperature-controlled generator. Bolus dose of heparin (100 unit/kg) was administered intravenously prior to the initiation of ablation procedure. The ablation was considered successful if the following conditions were fulfilled: loss of abnormal pathway for atrioventricular reentrant tachycardia or noninducibility of tachycardia, followed by the termination of tachycardia during ablation for primary atrial tachycardia, ventricular tachycardia, and scar-related atrial flutter. After ablation, the patient was hospitalized overnight, and a continuous heparin infusion was implemented for all patients undergoing left heart ablations. Activated partial thromboplastin time was maintained, at a level of twice the normal range. Low doses of aspirin were also administered for a month to the cases in which a left heart lesion had been made. All patients were followed up at intervals of 1, 3, 6 and 12 month(s).

**Statistics**

Values are expressed as the mean ± standard deviation. Univariate comparisons of continuous variables were conducted using the Student's t test. Univariate analyses of the differences in proportion between the two groups were accomplished

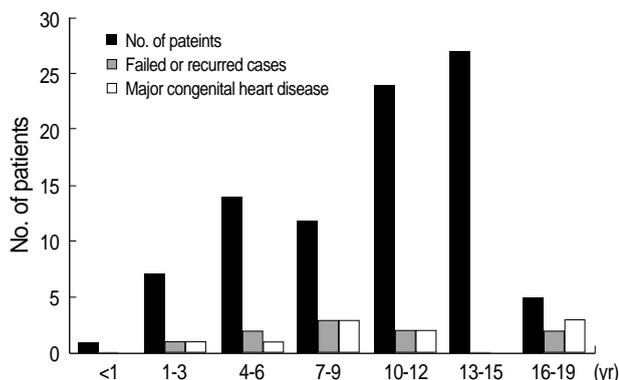


Fig. 1. This bar graph shows the age distributions of the patients undergoing radiofrequency catheter ablation. The age of the total of 100 patients ranged from 10 months to 19 yr, with a mean of 10.2 ± 4.1 yr. The failed or recurred cases, as well as the major congenital heart disease patients were distributed nonspecifically throughout the entire age range.

using the  $\chi^2$  test.

**RESULTS**

**Patient characteristics**

The age of the total 100 patients ranged from 10 months to 19 yr, with a mean of 10.2 ± 4.1 yr. Twelve of the patients were less than 5 yr old. The age distributions are shown in Fig. 1. The male to female ratio was 52:48. The indications for RFCA are listed in Table 1. Tachycardia-induced cardiomyopathy was observed in 5 patients (4 patients with ectopic atrial tachycardia, 1 patient with idiopathic left ventricular tachycardia). Ventricular function recovered after successful RFCA in all patients by 3 months after the procedure. One infant, who was 10 months old and the youngest patient of this series, presented with fetal tachycardia. The nature of this patient's tachycardia was determined to be congenital junctional ectopic tachycardia. This tachycardia was poorly controlled by antiarrhythmic drugs, including amiodarone and flecainide. Eventually, this patient became hypotensive and acidotic, so we performed emergent RFCA. Among 100 total RFCA cases, the most frequent indication was that the patient or parents preferred definitive RFCA management to chronic medication for the treatment of recurrent symptomatic tachycardia.

**Types of arrhythmia**

The types of tachycardia are summarized in Table 2, 3. The most frequently observed type of tachycardia was atrioventricular reentrant tachycardia (AVRT), which was observed in 67 patients. Wolff-Parkinson-White (WPW) syndrome was also associated with induced AVRT, and seen in 35 patients. In only three of these patients, antidromic tachycardia was also induced during EPS. Two of the 67 AVRT patients exhibited characteristics of permanent junctional reciprocating tachycardia, with a slowly conducting accessory pathway (AP) in the posteroseptal area. Multiple accessory pathways were found in 9/67 patients (13.4%). Multiple AP were documented by the following observations: (a) changed retrograde ventriculo-atrial conduction patterns during the same tachycar-

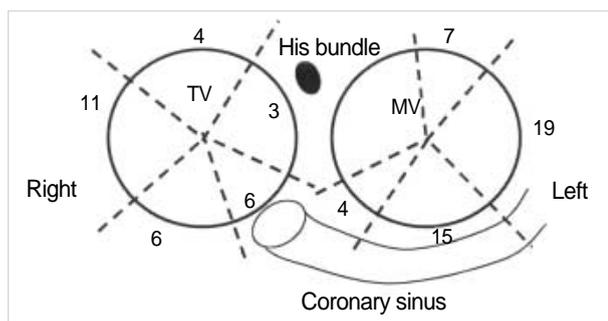
Table 1. Indications of radiofrequency catheter ablation in children

Indications	No. of patients
Syncope or presyncope	4
Tachycardia induced cardiomyopathy	5
Persistent tachycardia or frequent recurrence with medication	21
Recurrent symptomatic tachycardia, parent's choice (age>5 yr)	63
Arrhythmia treatment before surgery	5
Drug side effect	2

**Table 2.** Tachycardia types and results of ablation procedure

Tachycardia	No. of cases	Age (yr)	Acute success	Recurrence	Final success
AVRT	68	9.0±3.7	66/67	4/56 single AP 3/9 multiple APs	66/67
AVNRT	16	13.0±2.5	16/16	0/16	16/16
Ectopic atrial tachycardia	5	6.4±3.3	5/5	0/5	5/5
IART	3	16.0±3.6	2/3	1/2	1/3
Junctional ectopic tachycardia	1	0.8	1/1	0/1	1/1
Twin node tachycardia	1	4	0/1		1/1
JET+IART (AV node ablation)	1	11	1/1	0/1	1/1
Ventricular tachycardia	6	12.1±4.9	6/6	0/6	6/6
Total	100	10.2±4.1	97/100	8/97	97/100

AV, Atrio-ventricular; AVRT, Atrioventricular reentrant tachycardia; AVNRT, Atrioventricular nodal reentrant tachycardia; IART, intraatrial reentrant tachycardia; JET+IART, junctional ectopic tachycardia and intraatrial reentrant tachycardia; AP, accessory pathway.



**Fig. 2.** This diagram depicts the accessory pathway locations of 67 patients with atrioventricular reentrant tachycardia. The multiple pathways were marked separately in this figure. The left lateral atrioventricular groove was the most frequent location of the accessory pathway. TV, tricuspid valve; MV, mitral valve.

dia, (b) multiple patterns of pre-excitation on surface ECGs, and (c) two or more separate successful ablation sites, belonging to different divisions of the mitral or tricuspid valve annulus (Fig. 2).

AV nodal reentrant tachycardia (AVNRT) was detected in 16 patients. We performed RFCA in 16 patients for other tachycardias: primary atrial tachycardia, junctional ectopic tachycardia (JET), ventricular tachycardia (VT) and intraatrial reentrant tachycardia (IART).

### Results of RFCA in normal or trivial cardiac anomaly

#### AVRT in normal or trivial structural anomaly

AVRT was induced in 62 patients with normal or trivial structural anomalies. Cardiomyopathy or myocardial dysplasia (n=4), cardiac tumor presumed to be rhabdomyoma (n=1),

**Table 3.** Associated cardiac disease and tachycardia

Disease	Tachycardia	No. of cases
Not-repaired		
Idiopathic Cardiomyopathy	AVRT	2
Myocardial dysplasia	Ectopic atrial tachycardia	1
	AVRT	1
Ebstein's anomaly	AVRT	3
Atrial septal defect	AVNRT	1
Cardiac Tumor	AVRT	1
Repaired		
Functional single ventricle		
Cavopulmonary shunt state	AVRT	2
AV valve replacement	IART	1
Fontan operation	AVRT	1
	IART	1
	IART+JET	1
Tetralogy of Fallot	IART	1
Ventricular septal defect	AVRT	1
Total		17

The same abbreviations as Table 2.

and simple septal defects (n=2) exerted no influence on the technique and results of the procedure. The AP distribution, determined by a successful ablation site, was illustrated in Fig. 2. Multiple AP was counted separately. RF ablation for multiple AP required longer fluoroscopic times than did that for single AP patients ( $53.9 \pm 4.8$  vs.  $36.2 \pm 24.1$  min;  $p=0.03$ ). In 45 patients, the accessory pathway was found in the left heart, around the mitral valve annulus. We approached in an antegrade manner, via the patent foramen ovale in 5 patients, and utilized a Brockenbrough trans-septal needle perforation of the interatrial septum in 40 patients. Only one patient required a retrograde submitral approach, because her posteroseptal accessory pathway could not be eliminated by both right and left atrial approaches. RF ablation failed in only one patient, who exhibited concealed para-Hisian AP. The initial RFCA success rate was 61/62 (98.4%). The recurrence rate was 3/9 (33.3%) for the multiple AP patients, and 3/53 (5.7%) for the single AP patients ( $p=0.03$ ). There were no differences detected in the success rates or recurrence rates with regard to right side and left side APs (Fig. 2). Failed and recurred cases are summarized in Table 4.

#### Slow pathway ablation in AV nodal reentrant tachycardia (AVNRT)

AVNRT was detected in 16 patients. The age of the AVNRT cases was older than that of the AVRT cases ( $13 \pm 2.5$  vs.  $9.0 \pm 3.7$  yr respectively;  $p=0.002$ ). Radiofrequency ablation by electroanatomic guide was performed via a posterior approach. We achieved successful slow pathway ablation or slow pathway modification in all 16 patients. The fluoroscopic time for ablation was  $28.7 \pm 9.9$  min, which appeared to be shorter than that required for AVRT ablation. However, this difference did not reach statistical significance ( $p=0.07$ ). AV node conduction was determined to be intact after ablation, and no recurrence was observed in any of the patients.

**Table 4.** Failed or recurred cases

Cardiac disease	Tachycardia characteristics	Final Outcome
Failed cases		
Normal structure	Concealed paraHissian AP	Well controlled by beta blocker for 4 yr
RI, CAVSD, s/p BCPS	Twin AV node tachycardia	Cryoablation during Fontan operation, no recur for 2 yr
RI, CAVSD, s/p AVVR	IART	Amiodarone, expired after 1 yr due to heart failure
Recurred cases		
RI, CAVSD, s/p Fontan	WPW, AVRT	Reattempt to RFCA, success
Double inlet RV, s/p Fontan	IART	Sotalol, decreased frequency
Tumor	WPW, AVRT, multiple APs	Reattempt to RFCA, success
Normal structure	PJRT	Reattempt to RFCA, success
Normal structure	AVRT, multiple APs	Reattempt to RFCA, success
Normal structure	AVRT, multiple APs	Reattempt to RFCA, success
Normal structure	WPW, single left side AP	Reattempt to RFCA, success
Normal structure	WPW, single right side AP	Reattempt to RFCA, success

RI, right isomerism; CAVSD, complete atrioventricular septal defect; s/p BCPS, status post bi-directional cavopulmonary shunt; s/p AVVR, status post common atrioventricular valve replacement; s/p Fontan, status post Fontan operation; WPW, Wolff Parkinson White syndrome; RFCA, radiofrequency catheter ablation; otherwise the same abbreviations as Table 2.

**Table 5.** Fluoroscopic time

	No. of cases	Times (min)
Normal or trivial heart anomaly	90	34.3 ± 15.2
Major heart anomaly	10	51.4 ± 37.6
Single accessory pathway	59	36.2 ± 24.1
Multiple accessory pathways	9	53.9 ± 4.8
AVRT	68	40.5 ± 25.0
AVNRT	16	28.7 ± 9.9
Ectopic atrial tachycardia	5	32.2 ± 11.1
Ventricular tachycardia	6	33.0 ± 10.1
IART	3	63.5 ± 44.9
Total	100	38.3 ± 22.6

The same abbreviations as Table 2.

#### Ectopic atrial tachycardia

Ectopic atrial tachycardia was demonstrated in 5 patients, in an age range of between 3 to 10 and a mean of  $6.4 \pm 3.3$  yr. Four of these patients exhibited decreased left ventricular ejection fractions, as well as chamber enlargement. Three patients exhibited persistent tachycardia despite medical treatment. RFCA was performed during the tachycardia, and guided by both unipolar and bipolar mapping signals in all cases. Successful foci exhibited earlier activation, by  $19 \pm 8$  msec, than at the beginning of the ectopic P wave. Ectopic foci were located in the right atrial appendage in 2 patients, in the crista terminalis in 2 patients, and left atrial appendage in 1 patient. We achieved the successful ablations of ectopic foci in all patients, without recurrence. Left ventricular function recovered after ablation in all four patients with tachycardia-induced cardiomyopathy.

#### VT in normal heart

Six patients (age:  $12 \pm 4.9$  yr) exhibited idiopathic VT. None exhibited structural heart disease. One patient suffered from tachycardia induced cardiomyopathy. Four patients had idiopathic VT in the left ventricle, and two in the right ven-

tricle. RF ablation was performed for LV ventricular tachycardia via Purkinje signal mapping, and successful ablations were achieved at the posteroseptum on the left ventricular side. For two patients, whose VT originated from the RV outflow tract, VT pace-mapping proved helpful in the successful ablation. None of the six patients exhibited VT recurrence after ablation.

#### Junctional ectopic tachycardia

One ten-month-old male infant exhibited persistent junctional ectopic tachycardia. We performed emergent RFCA, as the patient was in shock state in spite of antiarrhythmic medication. Because there was no retrograde atrial conduction through AV node during the tachycardia, we attempted an empirical RF ablation. Tachycardia was eliminated by the application of 50°C RF energy to the mid-part of the Koch's triangle. A very transient complete heart block was observed, but fortunately, AV nodal conduction recovered within 6 sec. This patient has exhibited normal AV node function without any recurrence of tachycardia for 2-yr follow-up.

#### Results of RFCA with associated heart disease

Among 100 total patients, associated cardiac disease was detected in 17 patients (Table 2). Ten of these patients had significant cardiac anomalies, which complicated both mapping and ablation procedures. Three patients exhibited Ebstein's anomalies associated with AVRT, one patient had a repaired tetralogy of Fallot with IART, and the remaining six patients exhibited complex cardiac anomalies with single ventricle physiology associated with AVRT (n=3), IART (n=2), and IART coupled with focal junctional tachycardia (n=1). The fluoroscopy time recorded during the RFCA procedure appeared to be longer in patients with major congenital heart disease than in those with normal or trivial heart anomalies with weak statistical significance ( $51.4 \pm 37.6$  vs.  $34.3 \pm 15.2$

min respectively;  $p=0.06$ ) (Table 5).

#### AVRT in congenital heart disease

Among 3 patients with Ebstein's anomaly, two had WPW syndrome. Atrioventricular accessory pathways were located in the right posterior site in 3 of the patients. One patient exhibited multiple pathways in the right posterior and right midseptal area. All right posterior pathways were successfully ablated at the electrical atrioventricular junction. The ablation of accessory pathways in patients with functional single ventricle was attempted in two of the patients. A 22-month old patient with a double-inlet right ventricle was slated to undergo a Fontan operation. RFCA was performed prior to the Fontan operation, as we considered catheter access to the AV groove to be limited after the completion of a Fontan operation. Another 9-yr old girl with WPW syndrome, an atrioventricular septal defect, and a double outlet right ventricle had already undergone a fenestrated lateral tunnel-type Fontan operation prior to RFCA. The initial RF attempt was performed via a retrograde approach because we failed to get the femoral venous access. Mapping of the accessory pathway beneath the common AV valve was difficult, due to the atypical AV junctional position, using a conventional mapping system. The anteriorly located accessory pathway was successfully ablated on the atrial side via retrograde approach. However, recurrence was noted on the next day, and symptomatic tachycardia recurred 4 months after the performance of RFCA. Finally, the accessory pathway was eliminated by the third ablation procedure, which had been performed in an antegrade manner, through the Fontan baffle fenestration.

#### Twin AV node-related tachycardia

One patient with right isomerism, complete atrioventricular septal defect, and a double-outlet right ventricle, also developed narrow QRS tachycardia by the single ventricular extrastimulus. EPS revealed the presence of a twin AV node (both anterior and posterior nodes) which provided the reentry circuit. As the patient had been previously scheduled for a Fontan operation, we planned a concomitant cryoablation in the operating room following a few failed test RF ablations around the posterior node.

#### Post-surgical IART

Three patients exhibited medically intractable postoperative IART ( $15.6 \pm 4.1$  yr old) These patients had previously undergone a Fontan operation for a single inlet right ventricle in one patient, a common AV valve replacement with a bi-directional cavopulmonary shunt for right isomerism in one patient, and a total correction of tetralogy of Fallot in one patient. Concealed entrainment mapping during tachycardia revealed that the critical isthmus was located in the corridor between the surgical scar and the inferior vena cava in two patients. In one patient, the IART exhibited a typical counterclockwise periannular circuit around the tricuspid

valve. The initial success of RF ablation was achieved in two patients. However, 3 months later, the IART recurred in one Fontan patient, and this has been controlled, in part, by sotalol.

#### AV node ablation in a Fontan patient with multiple intractable tachycardia mechanisms

One lateral tunnel Fontan patient (double inlet right ventricle with mitral valve hypoplasia) had frequent attacks of focal junctional tachycardia, with simultaneous IART and sinus node dysfunction. As this patient had had several episodes of near syncope and also exhibited a tendency toward severe sinus bradycardia followed by junctional ectopies or bouts of IART, a DDDR pacemaker was implanted, and amiodarone was prescribed. In spite of these measures, the patient continued to suffer from recurrent JT or IART. Although we had planned to eliminate the arrhythmic focus, 2 types of rapidly-conducting induced IART (cycle lengths of 262 msec and 259 msec and 1:1 AV conduction) and rapid JT appeared to be too dangerous to map. Therefore, we decided to ablate or modify the AV node. His bundle electrogram (HBE) was recorded antegradely, via fenestration at the posterior AV groove. As an initial attempt to modify the AV node did not result in the abolition of the rapid JT, we attempted a second RFCA. A complete AV block resulted 6 sec after a second ablation attempt in the HBE recording site. This patient is now doing well, with no symptoms related to tachycardia over 22 months, and remains on sotalol with a pacemaker.

#### Complications of the procedure

Three patients complained of transient chest pain after the procedure. This chest pain did not appear to be associated with ischemic ECG patterns or pericardial effusion. The chest pain subsided spontaneously by the following day in all of the patients. Transient complete right bundle branch block was observed in 8 patients during the catheter work, and this resolved itself within several minutes or hours. No patients exhibited procedure-related valve dysfunctions, myocardial perforation, or unpredicted heart blocks. There were also no documented thromboembolic events related to the procedure within one year of the procedure.

## DISCUSSION

RFCA has recently been accepted as a viable management option for tachycardia, and the results of RFCA in pediatric patients has improved substantially (6-9). Moreover, since January 2004, Korean medical insurance has supported the medical costs associated with the RFCA procedure, and therefore reports regarding the results and clinical impacts of this procedure in the Korean pediatric population are currently a matter of some necessity. This procedure needs to be proven to be a measure of improved patient safety and outcomes.

The present report summarized the efficacy and limitation of pediatric RFCA for the treatment of a variety of tachycardia types, with or without congenital heart disease, in single institute in Korea. At our institute, radiofrequency ablations were performed according to the guidelines established by the NASPE expert consensus conference (10). Most of our patients (61%) underwent RFCA according to their designation as class IIB patients. These patients exhibited symptomatic recurrent tachycardia (age >5 yr), and RFCA was performed as an alternative to chronic antiarrhythmic therapy. However, most would agree that successful RFCA yields greatly beneficial results for both our patients and their parents.

The special considerations for pediatric RFCA, as opposed to the adult population, are as follows; (a) favorable natural history of infantile tachycardia, (b) results of pediatric RFCA, (c) associated heart disease, (d) information available from studies in young animal models, (e) radiation safety considerations, (f) complications of pediatric RFCA, (g) cost-effectiveness analyses in the pediatric population, and (h) sedation issues in the young. The natural history of pediatric tachycardia is, in general, favorable (11). In young patients, especially in infants, spontaneous remission is common. The manifested accessory pathways noted during infancy disappear in about 70% of the patients during the follow-up period. However, 30-50% of patients may experience recurrence in later childhood (12, 13). Due to the generally favorable natural history statistics, we performed AVRT ablation mostly in patients who were 5 yr of age or older. All cases associated with the performance of RFCA before 5 yr of age in our series exhibited medically intractable tachycardia recurrences, or tachycardia-induced cardiomyopathy.

The success rate and recurrence of RFCA reported in this series is comparable to those seen in previous reports (2, 4, 7-9). The success rate of RFCA for the treatment of paroxysmal supraventricular tachycardia, including AVRT and AVNRT, with or without congenital heart disease was 82/83 (98.8%), the recurrence rate was 7/83 (8.4%), and the ultimate success rate following subsequent procedures was 82/83 (98.8%). The success rate and recurrence rate of right side vs. left side accessory pathways were similar. We experienced neither failure nor recurrence in patients with EAT, JET, and idiopathic VT, although our study involved only a small number of such cases. Our data also revealed that prolonged fluoroscopic time was associated with multiple accessory pathways, or congenital heart anomalies.

The management of patients suffering from congenital heart disease may be complicated by serious arrhythmias, due to WPW syndrome, or by atrial arrhythmias, including IART, after cardiac surgery. Ablation techniques using radiofrequency currents are presently revolutionizing the management of arrhythmias. Several common features among patients suffering from congenital heart disease can complicate RFCA when used as a treatment for supraventricular tachycardia, and might be expected to reduce its acute and long-term efficacy, as well

as increasing the frequency of procedure-related complications. The anatomical landmarks which are commonly used to determine the location of the AV node and the annulus of the atrioventricular valves are often absent or distorted. Catheter access may also prove to be very difficult, owing to surgical interventions, systemic venous anomalies, and acquired venous occlusion. Moreover, pulmonary and hemodynamic impairment can increase the risks of the procedure (14-16). The association between accessory pathways and Ebstein's anomalies has been well-documented. We performed successful ablations at the electrical atrioventricular annulus of the tricuspid valve. Multiphasic low intensity signals of diseased atrialized ventricular myocardium could be discerned by cautious and tedious atrial pacing, at Wenckebach block cycle length. We also confirmed the relative difficulty of RF ablation for the treatment of WPW syndrome after the completion of a Fontan operation. We agree that RFCA should be recommended for patients with impending congenital heart disease surgery, in cases in which vascular or chamber access may be restricted after surgery (10).

Recurrence tends to be observed within 3-6 months after the ablation of the accessory pathways, and this held true in our study as well. In children, the risks of radiofrequency ablation appear, from the results of follow-up evaluations, to be relatively low. Longer-term follow-up of children undergoing radiofrequency ablations will be necessary in order to determine whether or not coronary abnormalities or serious new arrhythmias are likely to develop.

IART is a common problem in patients with congenital heart disease, especially after a successful Fontan procedure. Relatively low success rates and high recurrence rates, have been reported, especially after ablation guided by conventional entrainment mapping techniques (17-19). However, in patients with successful RF ablation, the frequency of subsequent events can be reduced. New electroanatomic 3-dimensional mapping techniques will facilitate the precise mapping of complicated reentrant circuits and scar zones (19).

Twin AV node-related atrioventricular reentrant tachycardia is quite a rare condition, and is usually associated with heterotaxy syndrome or complicated complete atrioventricular septal defect requiring Fontan-type palliation (20, 21). As tachycardia in Fontan patients almost always induces serious hemodynamic compromise, aggressive management with RFCA or surgical ablation during concomitant surgery should be considered in any symptomatic tachycardia patients. Additionally, the natural course of twin AV node-related tachycardia remains to be fully elucidated.

In conclusion, regardless of the presence or absence of cardiac anomalies, the overall acute success rate of pediatric RFCA in our study was 97%, the recurrence rate was 8.2%, and the final success rate was 97%. No major complications were noted. This experience confirmed the efficacy and safety of RFCA in the management of pediatric tachycardia patients.

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