Clinical Medicine Insights: Cardiology

ORIGINAL RESEARCH

Radiofrequency Catheter Ablation in Children with Supraventricular Tachycardias: Intermediate Term Follow Up Results

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Abstract

The Purpose of the Study: Radiofrequency (RF) catheter ablation represents an important advance in the management of children with cardiac arrhythmias and has rapidly become the standard and effective line of therapy for supraventricular tachycardias (SVTs) in pediatrics. The purpose of this study was to evaluate the intermediate term follow up results of radiofrequency catheter ablation in treatment of SVT in pediatric age group.

Methods: A total of 60 pediatric patients (mean age = 12.4 ± 5.3 years, ranged from 3 years to 18 years; male: female = 37:23; mean body weight was 32.02 ± 12.3 kg, ranged from 14 kg to 60 kg) with clinically documented SVT underwent an electrophysiologic study (EPS) and RF catheter ablation at Children's Hospital Mansoura University, Mansoura, Egypt during the period from January 2008 to December 2009 and they were followed up until October 2011.

Results: The arrhythmias included atrioventricular reentrant tachycardia (AVRT; n = 45, 75%), atrioventricular nodal reentrant tachycardia (AVNRT; n = 6, 10%), and atrial tachycardia (AT; n = 9, 15%). The success rate of the RF catheter ablation was 93.3% for AVRT, 66.7% for AVNRT, and 77.8% for AT, respectively. Procedure-related complications were infrequent (7/60, 11.7%), (atrial flutter during RF catheter ablation (4/60, 6.6%); ventricular fibrillation during RF catheter ablation (1/60, 1.6%); transient complete heart block during RF catheter ablation (2/60, 3.3%)). The recurrence rate was 8.3% (5/60) during a follow-up period of 34 ± 12 months.

Conclusion: RF catheter ablation is an effective and safe method to manage children with SVT.

Keywords: radiofrequency catheter ablation, supraventricular tachycardias, children

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Introduction

Supraventricular tachycardia (SVT) is the most common tachyarrhythmia in pediatric patients, and accounts for more than 90% of pediatric arrhythmias.[1] It is defined as a sustained tachyarrhythmia originating above the bundle of His[2] although its exact incidence is unknown, it has been estimated to affect between 1 in 250 to 1 in 25,000 children.[3] Some mechanisms of SVT are associated with congenital heart disease; however most children with SVT have structurally normal hearts.[4,5] Unlike the adult population, atrioventricular reentrant tachycardia (AVRT) is the most common form of SVT, which constitutes two-thirds of the pediatric patients, followed by atrioventricular nodal reentry tachycardia (AVNRT) and atrial tachycardia (AT).[6]

Radiofrequency (RF) catheter ablation was initially applied clinically in adult patients[7] and later became available as a treatment modality in pediatric patients with tachyarrhythmias.[8,9]

Therefore, RF catheter ablation represents a major advance in the management of children with cardiac arrhythmias and has rapidly become the standard of care for the first-line therapy of SVTs.[10]

The present study aimed to evaluate the intermediate term follow-up results of radiofrequency catheter ablation in the treatment of SVT in pediatric age group.

Methods

Design of the study

This is a prospective observational study, which was conducted at Children's Hospital Mansoura University, Mansoura, Egypt during the period from January 2008 to December 2009. It included all patients between 3–18 years of age with documented SVT and suspected to be AVRT, AVNRT and AT who were followed up in our centre or referred to us for EPS and RF catheter ablation, after failure of traditional pharmacological management. Diagnosis of SVT was based on 12-leads surface electrocardiogram.

The following criteria were considered as exclusion criteria: (1) age younger than 3 years or older than 18 years, (2) palpitation without documented tachycardia or evidence of manifest pre-excitation on 12-leads ECG, (3) associated complex congenital cyanotic heart diseases, (4) atrial flutter or atrial fibrillation in absence of accessory pathway.

Patients

Because Mansoura University Children's Hospital serves five governorates in the delta region, there are about 700–1000 patients attending our general pediatric outpatient clinic and the emergency department daily (about 500,000 patients during the study period).

Out of the total number of children, about 2500 patients attended our cardiology out-patient clinic or admitted to our hospital during the study period (from January 2008 to December 2009), and among them there were 250 of 2500 patients (14%) who complained of different types of arrhythmias.

SVT was diagnosed in 280 of 350 patients (80%), from whom we identified according to our inclusion and exclusion criteria to do EP study & RF ablation to 60 of 280 patients (21.4%). The mean age of the 60 patients was 12.4 ± 5.3 years (ranged from 3 years to 18 years); M/F ratio is 1.6 of 1(37 male:23 female). The mean age for males was 13.55 ± 4.86 years and for females it was 10.3 ± 5.61 years, mean body weight was 32.02 ± 12.3 kg (ranging from 14 kg to 60 kg), Table 1.

All patients were subject to full history taking regarding onset, frequency of palpitation, syncope, chest pain, dyspnea, heart failure, drug intake and family history of arrhythmia. Also they were subjected to resting 12-leads surface ECG and ECG during the attack. Echocardiography was done for detection of structural heart diseases.

Written informed consent for the electrophysiological study was obtained from the parents of the patients after approval by the institutional ethics

Table 1. Basic clinical characteristics of the 60 Patients with SVT.

Age (years) (mean ± SD)	12.4 ± 5.3
BW (kg) (mean ± SD)	32.02 ± 12.3
Male: Female	37 (61.7%):23 (38.3%)
Associated congenital heart disease:	5 (8.3%)
Arrhythmia mechanism:	
AVRT	Total no = 45 (75%); 38 (Manifest) & 7 (Concealed) *Left sided AP: 28 (62.2%) *Right sided AP: 9 (20%) *Septal AP: 8 (17.8%)
AVNRT	Total no = 6 (10%)
AT	Total no = 9 (15%); 6 (Right sided) & 3 (Left sided)

and review board committee at our hospital. All antiarrhythmic agents were discontinued for 5 half-lives (or 3 days) before the study.

Electrophysiologic study and radiofrequency catheter ablation

Electrophysiologic study was performed under general anesthesia using propofol as a hypnotic (2–3 mg/kg), Fentanyl as a short acting opioid (1 μgm/kg), cisatracurium as muscle relaxant (0.1 mg/kg).

Percutaneous cannulation using the Seldinger technique was used for introducing the catheters. Left subclavian vein puncture was done for introducing a decapolar catheter (5 or 6 French, F) into coronary sinus (CS) to record the left atrial activity; left femoral vein puncture was done to introduce two quadripolar catheters (5 or 6 F) to record His bundle (H), and right ventricle activity (V); right femoral vein puncture was done for introducing ablation catheter (5–7 F) which was used for recording RA activity (A) and also used for ablation. For left sided ablations, Patent Foramen Ovale (PFO) was searched for, if absent either trans-septal approach was performed or a right femoral artery puncture was done for retrograde aortic approach. The catheters were positioned fluoroscopically, preferably with biplane fluoroscopy.[11]

Anticoagulation was given in the form of heparin 50 IU/kg initially and if a femoral artery puncture was performed, a continuous saline infusion containing heparin 10 IU/kg was given.

The study of each case began with recording the sinus rhythm and analyzing its component intervals to provide baseline information of the patient's conduction system.[12]

A stimulation protocol comprised of atrial and ventricular incremental pacing and extrastimulation was performed to detect the electrophysiologic characteristics, including the: (1) antegrade and retrograde 1:1 conduction cycle length (CL), (2) the effective refractory period (ERP) of the AV node, (3) antegrade and retrograde AV nodal conduction patterns, (4) antegrade and retrograde accessory pathways (AP) conduction patterns, and (5) induction mode and type of tachycardia. If a tachycardia could not be provoked during the baseline stimulation protocol, isoproterenol was continuously infused at a rate of 1 to 6 μg/min to increase the patient's heart rate to at least 20% above the resting sinus rate.[10]

After completion of the basic electrophysiologic study, we identified the various different types of tachycardias. The traditional method of ablation uses radiofrequency energy to heat and obliterate the site of origin of the SVT mechanism.[13]

Atrioventricular reentrant tachycardia (AVRT)

We located the sites of the accessory pathway (AP) around the atrioventricular annulus by mapping the shortest atrio-ventricular (AV) interval (earliest local ventricular activation time) during sinus rhythm in manifest Wolf-Parkinson-White (WPW) syndrome (Fig. 1) and the shortest ventriculo-atrial (VA) interval (or the earliest local atrial activation time) during ventricular pacing or during AVRT. RF current was delivered at the site of shortest AV—VA during sinus rhythm or ventricular pacing respectively. Successful ablation was defined as either no inducible AVRT or loss of preexcitation (Fig. 2).[14]

Atrioventricular nodal reentrant tachycardia (AVNRT)

AVNRT was diagnosed by the presence of sudden AH jump ≥50 ms during tachycardia, retrograde atrial activation (Echo beat), and simultaneous A & V (VA $<$ 60 ms in His recording catheter) (Fig. 3).[14]

Ablation of AVNRT targets the slow pathway. We located the slow pathway region under the guidance of fluoroscopy and observing the electrogram. The ablation catheter is directed into low right ventricle near the posterior septum and is then withdrawn until an electrogram is recorded with a small atrial electrogram and a large ventricular electrogram (A:V ratio $<$0.5). Specific ablation sites along the posterior portion of the tricuspid annulus can be selected based either on the appearance of the local atrial electrogram, fractionated atrial electrogram with a late slow potential or based on anatomical site (at level of coronary sinus os). Appearance of junctional rhythm during the application of RF energy (with a maximum power $<$35 Watts) is a marker of successful ablation, in addition there is no induction of AVNRT nor induction of an echo beat during isoproterenol infusion.[15]

Atrial Tachycardia (AT)

Mapping of ectopic AT focus is performed during the tachycardia by moving the mapping-ablation catheter

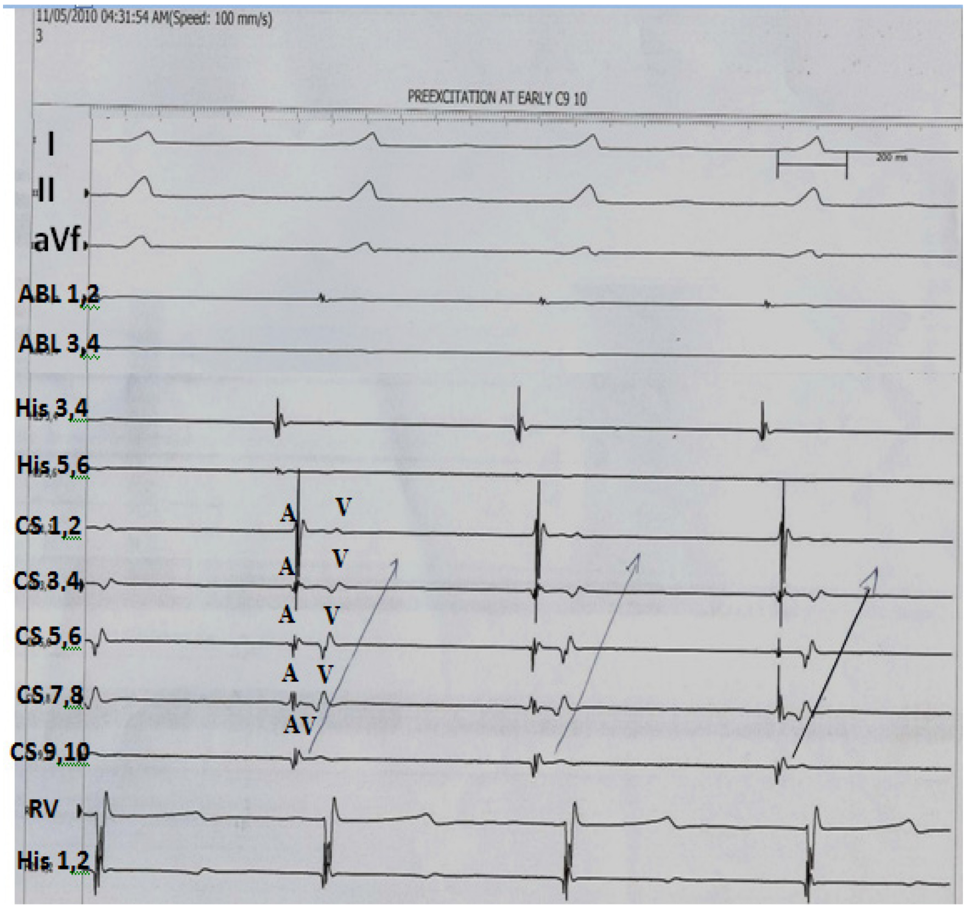

Figure 1. Intracardiac tracing of 5 years old boy diagnosed as WPW.
Note: During sinus rhythm, the shortest AV interval (pre-excitation) is recorded at CS 9, 10 (posteroseptal AP).
Abbreviations: His, His catheter; CS, coronary sinus catheter; RV, Right ventricle catheter; ABL, ablation catheter; A, atrial activity; V, ventricular activity.

throughout multiple sites in the right atrium or left atrium (through PFO or via trans-septal puncture) under biplane fluoroscopic guidance. The local atrial activation time (measured as the earliest high-frequency and high-amplitude signal on a bipolar recording) can be indexed against the onset of the P wave on the surface ECG (which preceded the surface P wave by $\geq$30 ms) to identify the likely site of the ectopic AT focus origin.[16]

Successful ablation was defined as termination of the tachycardia by RF current and failure of induction of AT using isoproterenol infusion, atrial pacing or atrial extra-stimulation.[10]

Follow-Up Evaluation

After the procedure, the patients were monitored for 48 hours in an ordinary ward before discharge. Each patient was followed up at the outpatient clinic. The patients were followed up until October 2011 (34 $\pm$ 12 months) for the following: recurrence of symptoms, documented attacks of tachycardia, or manifest pre-excitation in resting ECG.

Data management and statistics

Data are expressed as mean $\pm$ standard deviation, S.D. (Statistical significance was defined as a P value $<$0.05). Statistical analysis was carried out using one way analysis of variance (ANOVA) followed by Tukey-Kramer multiple comparisons test. Also, unpaired Student's t-test was used as a test of significance for comparison between two arithmetic means of two different experimental groups. Chi-square test was used for comparison of two proportions.

Results

Clinical data

The main symptoms of patients included palpitation (100%), tachypnea (66.6%), chest pain (23.3%), syncope (26.6%) and heart failure (5%).

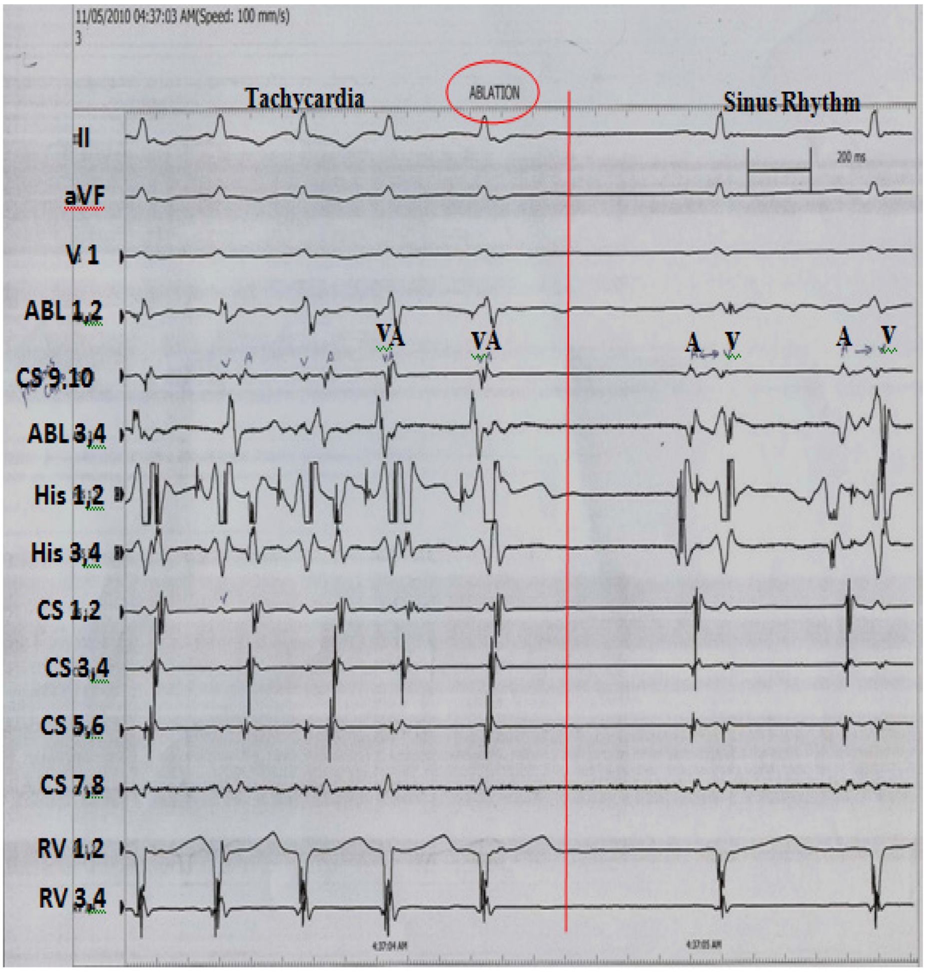

Figure 2. Intracardiac tracing of the same case at Fig. 1 during tachycardia (AVRT).
Note: The shortest VA time during tachycardia was recorded at CS catheter (9, 10). Ablation terminated the tachycardia and lead to disappearance of preexcitation and normalization of the ECG.
Abbreviations: His, His catheter; CS, coronary sinus catheter; RV, Right ventricle catheter; ABL, ablation catheter; A, atrial activity; V, ventricular activity.

There was no significant difference between male and female regarding each symptom. There was no significant difference among different types of SVT regarding heart rate during tachycardia; in AVRT (mean HR = 218.33 ± 5.85), in AVNRT (mean HR = 210 ± 10.95), in AT (mean HR = 205.5 ± 15.73).

Five patients had congenital heart diseases which represent 8.3% of the total number of the studied population; one patient with left anterior AP had secundum ASD, two patients with left lateral APs had mitral valve prolapse, one patient with right side AP had Ebstein malformation, and one patient with atrial tachycardia (left sided ectopic focus) had mitral valve prolapse. There was no significant difference among different types of SVT regarding presence of congenital heart disease. Also among our 60 patients, there were eight patients had a family history of SVT (6/45 patients with AVRT, 1/6 patient with AVNRT, and 1/9 patient with AT). but there was no significant difference among the three groups of SVT regarding presence of family history of arrhythmia.

Electrocardiographic data

The arrhythmias in the patients included: atrioventricular reentrant tachycardia (AVRT; n = 45, 75%), atrioventricular nodal reentrant tachycardia (AVNRT; n = 6, 10%), and atrial tachycardia (AT; n = 9, 15%), Table 1.

Among the patients presenting with AVRT (n = 45), 38 patients (84.4%) had manifest pre-excitation and only 7 patients (15.6%) had concealed APs.

Localization of the site of APs using resting ECG in manifest pre-excitation was confirmed after

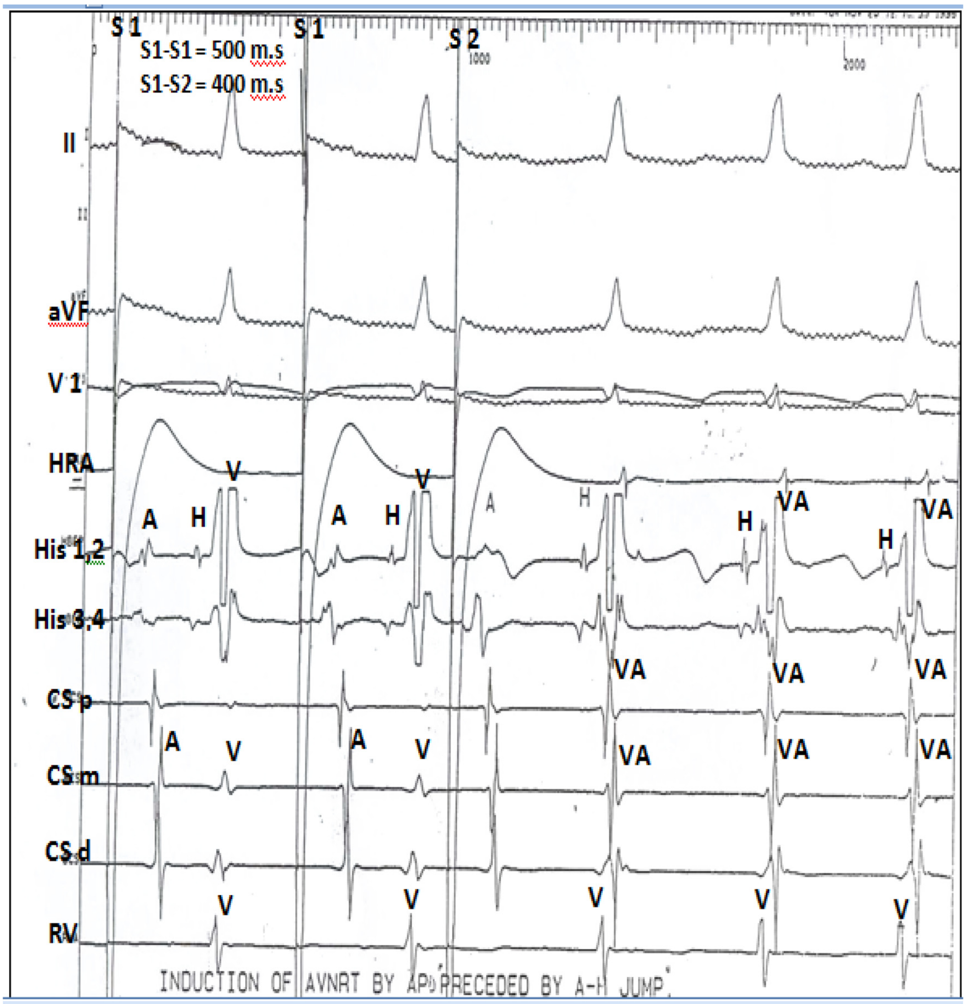

Figure 3. Intracardiac tracing of induction of AVNRT by atrial extra-stimulation.
Note: AVNRT is diagnosed here by concentric retrograde atrial activation, and simultaneous A & V.
Abbreviations: HRA, High Rt atrium; His, His catheter; CS, coronary sinus catheter; RV, Right ventricle catheter; A, Atrial activity; H, His activity; V, Ventricular activity.

Electrophysiologic study and was accurate in 35/38 patients (92%).

There was significant difference regarding the presence of pseudo r (in V1) and pseudo S/Q (in LII) on the surface ECG during tachycardia among patients with AVNRT (83.3%) versus patients with AVRT (6.7%) (P value <0.0001), Table 2.

Nine patients were diagnosed to have atrial tachycardia. Six patients (66.7%) had a right sided ectopic atrial focus (P wave was upright in leads I, II and inverted in aVR, P axis localized between 0 to + 90 degree), while three patients (33.3%) had a left sided ectopic atrial focus (P wave was upright in leads III, inverted or iso-electric in leads I, II and aVL, P axis localized between 90 to + 180 degree).

Electrophysiologic and radiofrequency catheter ablation data

In AVRT group, left sided APs represented the majority of cases (28/45, 62.2%), right sided APs were present in 9 patients (20%), while 8 patients had septal APs (17.8%). The detailed location of the APs is shown in Table 3.

The transvenous approach was used in ablation of AVNRT, atrial tachycardia of right sided origin, and right sided AP, (Fig. 4). The retrograde aortic approach was used in left sided AP. The trans-septal approach was used in two cases with left sided AP and in patients with atrial tachycardia of left sided origin.

The success rate of RF catheter ablation for all SVT was 53 of 60 patients. It was (42 of 45, 93.3%)

Table 2. Presence of pseudo r/S/Q in AVRT and AVNRT.

	AVRT (n = 45)		AVNRT (n = 6)	
	N	%	n	%
Positive pseudo r/S/Q	3	6.7	5	83.3
Negative pseudo r/S/Q	42	93.3	1	16.7
X^2	113.64			
P-value	≤ 0.0001*			

Note: There was extreme significant difference among AVRT and AVNRT regarding presence of pseudo r/s (using Chi-square test).

for AVRT, (4 of 6, 66.7%) for AVNRT, and (7 of 9, 77.8%) for AT, respectively, Table 4.

Failure of RF catheter ablation occurred in three patients diagnosed as AVRT; one child had AP located in the right posterior region (RP), another one had right posteroseptal AP (RPS), and the third one had left anterior AP (LA). Furthermore, two patients with AVNRT were not successfully ablated because of the repeated occurrence of transient heart block during the ablation. Also, RF catheter ablation failed in two patients with AT; one of them had a high right atrial AT and the other one had right lower lateral wall AT.

Procedure-related complications were present in 7/60 (11.7%). 4 patients (4/60, 6.6%) had atrial flutter during RF catheter ablation and were reverted to sinus rhythm by external DC shock. Only one patient (1/60, 1.6%) developed ventricular fibrillation during RF ablation and was also reverted to sinus rhythm by external DC shock. Two patients (2/60, 3.3%) had transient complete heart block during RF catheter ablation of AVNRT and were reverted to sinus rhythm by atropine. But neither perforations, pneumothoraxes, thromboembolisms nor deaths were noted.

Table 3. Intracardiac localization of APs.

Intracardiac Localization of APs	Number	%
Left anterior (LA)	3	6.7
Left lateral (LL)	13	28.9
Left posterior (LP)	12	26.7
Left posteroseptal (LPS)	3	6.7
Right posteroseptal (RPS)	2	4.4
Right anteroseptal (RAS)	1	2.2
Right midseptal (RMS)	2	4.4
Right anterior (RA)	4	8.9
Right posterior (RP)	5	11.1

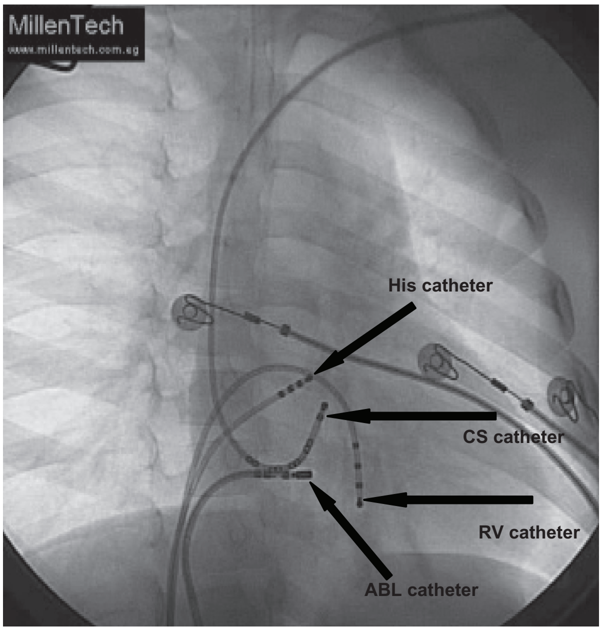

Figure 4. Fluoroscopic picture (RAO view, 30) showing ablation of posteroseptal AP.
Note: The ablation catheter is close to CS 9, 10.
Abbreviations: ABL catheter, Ablation catheter; RV catheter, Right ventricle catheter; CS catheter, coronary sinus catheter; His catheter.

Five patients (5/60, 8.3%) had recurrences of the same symptoms within 34 ± 12 months post RF catheter ablation. Two patients of them had AVNRT (2/60, 3.3%), two patients had APs (2/60, 3.3%); (one had left anterior AP, the other one had right anteroseptal AP), while one patient had right AT (1/60, 1.7%), Table 4.

In this study, there was no significant difference between different types of SVT regarding fluoroscopic time (*P* value = 0.4384), in AVRT it was 159.3 ± 44.94 minutes, in AVNRT was 140 ± 30.86 minutes, in AT was 145.5 ± 32.7 minutes.

Table 4. Outcomes of RF catheter ablation in the study population.

Success Rate of RFA:		
AVRT	42/45	(93.3%)
AVNRT	4/6	(66.7%)
AT	7/9	(77.8%)
Complications:	7/60	(11.7%)
Recurrence:		
Total	5/60	(8.3%)
AVRT	2/60	(3.3%)—Left anterior, Right antroseptal
AVNRT	2/60	(3.3%)
AT	1/60	(1.7%)—Right sided focus

The mean number of applications needed for success of ablation was 1.7 ± 0.56. There was no significant difference between different types of SVT regarding number of RF ablation attempts (*P* value = 0.0558), in AVRT it was 2.4 ± 0.67 times, in AVNRT was 1.17 ± 0.41 times, in AT was 1.56 ± 0.6 times.

Discussion

SVT is the most common symptomatic pediatric arrhythmia.[17] As many as 16 different mechanisms of pediatric SVT exist;[18] we focused on the three most common groups of SVT mechanisms in pediatrics: accessory pathway—mediated atrioventricular re-entry tachycardia (AVRT), atrioventricular nodal re-entry tachycardia (AVNRT), and atrial tachycardia (AT).[6]

In our study, the commonest mechanism of SVT was AVRT (75%), followed by Atrial Tachycardia (15%) then AVNRT (10%). This is in agreement with Sanatani et al[19] who concluded that accessory pathway—mediated re-entry tachycardias are the most common mechanism of SVT in infants and children and accounts for as many as 90% of cases of SVT in infants. Moreover, in another study conducted Perry[20] it was found that AVNRT is almost completely absent in infants and the frequency gradually increases in patients older than 1 year of age. Also, the incidence of AT in the pediatric population remains very small.[17]

Although some mechanisms of SVT are associated with congenital heart disease, most children with SVT have structurally normal hearts.[4,5] In our study, five patients out of 60 patients (8.3%) had congenital heart diseases; (ASD, mitral valve prolapse, and Ebstein anomaly). The association between the accessory pathways and Ebstein anomaly has been well documented in previous reports.[21–24]

There was no significant difference among different types of SVT regarding heart rate during the attacks; in AVRT (mean HR = 218.33 ± 5.85), in AVNRT (mean HR = 210 ± 10.95), in AT (mean HR = 205.5 ± 15.73). This agrees with a study performed by Doniger and Sharieff,[6] which revealed that the heart rate in infants with SVT frequently ranges from 220 to 280 BPM.

Snyder et al[25] reported that ECG criteria are able to accurately identify about 80% of AVRT, but incorrectly localize approximately 20% of paroxysmal SVT. In addition, Liberman et al[26] found that the mechanism of SVT could be identified in 91% of patients using Lead V1 and in 96% of patients using a combination of V1 and lead III. In our study, accurate localization of the site of APs using resting ECG was obtained in 35 of 38 patients (92%) with manifest pre-excitation of the AVRT group, while in 3 of 38 patients (8%) with manifest APs localization was not accurate.

Left sided APs represented the majority of the total number of AVRT group (28 of 45 patients, 62.2%), right sided APs in 9 patients (20%), while septal APs in 8 patients (17.8%), this agrees with Wellens et al[27] where it was found that more than 50% of APs are located at the left free wall, 20%–30% at the posterior septum, 10%–20% at the right free wall, and 5%–10% at the anterior septum.

In concordance with the results of Walsh et al,[28] who found a majority of ectopic foci in the right atrium, 66.7% of the children in our study (6 of 9 patients) had right sided ectopic foci.

In pediatric patients, Kugler et al[29] reported that ablation is successful during the acute phase in approximately 95%. While Chiu et al[11] showed that the immediate success rate was 92.6%. Moreover, Lee et al[10] reported that the success rate of the RF catheter ablation was 92% for AVRT, 97% for AVNRT, 82% for AT.

In our study, the total success rate of RF ablation was 88.3%. The success rate was (42 of 45, 93.3%) for AVRT, (4 of 6, 66.7%) for AVNRT, and (7 of 9, 77.8%) for AT.

The three cases of AVRT (3/45) who showed failure of RF catheter ablation, are two patients who had APs located in the right region (RP, RPS) and another one patient had AP in the left anterior position. Previous literature also demonstrated a relatively lower success rate for ablation in children with right-sided APs when compared with those with left-sided APs[29] possibly due to the thicker fibrous tissue, the more complicated anatomy (coronary sinus diverticulum), and more frequent epicardially located APs. Coronary sinus venogram was necessary for those patients with a failed catheter ablation of right posteroseptal APs.[17,30]

Moreover, the two cases (2 of 6) of AVNRT, who showed failure of RF catheter ablation, were due to repeated transient heart block during the ablation necessating stoppage of the procedure. Danford et al[31] suggested that to avoid the occurrence of inadvertent AV block in children with AVNRT, the RF catheter ablation procedure should include (1) a considerate and delicate temperature titration (50 °C–55 °C), (2) an initial spot on the lower third of Koch's triangle (close to the coronary sinus ostium), (3) attempts of ablation below the coronary sinus ostium if unsuccessful at the usual sites, and (4) ablative lesions as far away from the His bundle as possible (accurate His bundle catheter positioning during the ablation is mandatory).

Also, the two cases (2 of 9) of AT that showed failure of ablation were located in the right atrium. a relatively lower success rate (77.8%) was observed in the children with AT group in our study when compared with the other types of SVT. It is expected that technologic advances such as new mapping systems and increasing experience will improve the acute success rate, shorten the fluoroscopy time, and decrease the complication rate of AT ablation.[23,32–35]

Regarding the procedure related complications, we reported 11.7% complications. However, these complications were transient and were corrected during the procedure. No patients needed pacemaker implantation or open heart surgery.

The previous reports demonstrated that AV block was limited to patients with AVRT especially patients undergoing ablation of septal pathways, both right and left sided.[9,36,37] There were no reported deaths in our study although we know from previous reports that death is a possible complication of RF ablation procedures in children. Kugler et al[38] reported a total incidence of 4 (0.097%) procedure-related deaths in 4,135 children from 1991 to 1996, whereas Schaffer et al[36] reported an incidence of 0.12% deaths for patients with structurally normal hearts during ablation.

The recurrence rate of SVT in our study was (5 of 60, 8.3%) within 34 ± 12 months post RF catheter ablation. Two patients with AVNRT (2 of 60, 3.3%); two patients with APs (2 of 60, 3.3%), one had left anterior AP and the other child had right anteroseptal AP; also one patient with AT (1 of 60, 1.7%) had recurrence of the same arrhythmia.

This follow up period was relatively short when compared to other studies. Lee et al[10] showed that the recurrence rate was 4.7% during the long-term follow-up period (86 ± 38 months) in his study. While the rate of clinical recurrences during longterm follow-up (4 years) was 12.9% in the study conducted by Seixo et al.[39] Moreover, Chiu et al[11] reported early (3.7%) and late recurrence (7.4%) after 5.4 ± 3.7 years follow-up.

Further study is recommended so we can ablate children below 14 kg weight; also we can increase the number of the studied population.

In conclusion, RF catheter ablation is an effective and safe method for treatment of children with SVT, however a long follow-up period is recommended.

Abbreviations

RF, radiofrequency; SVT, supraventricular tachycardia; AVRT, atrioventricular reentrant tachycardia; AVNRT, atrioventricular nodal reentrant tachycardia; AT, atrial tachycardia; AP, accessory pathway; EPS, electrophysiologic study; PFO, patent foramen ovale; ASD, Atrial septal defect; AV, atrio-ventricular; VA, ventriculo-atrial; WPW, Wolff—Parkinson—White.

Disclosures

Author(s) have provided signed confirmations to the publisher of their compliance with all applicable legal and ethical obligations in respect to declaration of conflicts of interest, funding, authorship and contributorship, and compliance with ethical requirements in respect to treatment of human and animal test subjects. If this article contains identifiable human subject(s) author(s) were required to supply signed patient consent prior to publication. Author(s) have confirmed that the published article is unique and not under consideration nor published by any other publication and that they have consent to reproduce any copyrighted material. The peer reviewers declared no conflicts of interest.

References

1. Joung B, Lee M, Sung JH, Kim JY, Ahn S, Kim S. Pediatric radiofre quency catheter ablation: Sedation methods and success, complication and recurrence rates. *Circulation Journal*. 2006;70:278–84.
2. Hanisch D. Pediatric arrhythmias. *Journal of Pediatric Nursing*. 2001;16: 351–62.
3. Chun TUH, Van Hare GF. Advances in the approach to treatment of supraventricular tachycardia in the pediatric population. *Current Cardiology Rep*. 2004;6:322–6.
4. Green A, Kitchen B, Ray T. Supraventricular tachycardia in children: Symptoms distinguish from sinus tachycardia. *Journal of Emergency Nursing*. 2005;31:105–8.
5. Schlechte EA, Boramanand N, Funk M. Supraventricular Tachycardia in the Pediatric Primary Care Setting: Age related Presentation, Diagnosis, and Management. *Journal of Pediatric Health Care*. 2008;22:289–99.
6. Doniger SJ, Sharieff GQ. Pediatric dysrhythmias. *Pediatric Clinics of North America*. 2006;53:85–105.
7. Borggerfe M, Budde T, Podczeck A, Breithardt G. High frequency alternating current ablation of an accessory pathway in humans. *Journal of American College of Cardiology*. 1987;10:576–82.
8. Dick M, O'Connor BK, Serwer GA, LeRoy S. Use of radiofrequency current to ablate accessory connections in children. *Circulation*. 1991;84:2318–24.
9. Van Hare GF, Javitz H, Carmelli D, Saul JP, Tanel RE, Fischbach PS, et al. Prospective assessment after pediatric cardiac ablation: Demographics, medical profiles, and initial outcomes. *Journal of Cardiovascular Electrophysiology*. 2004;15:759–70.

10. Lee PC, Hwang B, Chen SA, Tai CG, Chen YJ, Chiang CE, et al. The results of radiofrequency catheter ablation of supraventricular tachycardia in children. *Pacing Clinical Electrophysiology*. 2007;30:655–61.
11. Chiu SN, Lu CW, Chang CW, Chang CC, Lin MT, Lin JL, et al. Radiofrequency Catheter Ablation of Supraventricular Tachycardia in Infants and Toddlers. *Circulation Journal*. 2009;73:1717–21.
12. Campbell RM, Strieper MJ, Frias PA, Danford DA, Kugler JD. Current status of radiofrequency ablation for common pediatric supraventricular tachycardias. *Journal of Pediatrics*. 2002;140:150–5.
13. Kantoch MJ. Supraventricular tachycardia in children. *Indian Journal of Pediatrics*. 2005;72:609–19.
14. Josephson ME. Supraventricular tachycardias. In: Josephson ME. (Ed.), Clinical Cardiac Electrophysiology: Techniques and Interpretation. Philadelphia: Lea&Febige. 1993;181–274.
15. Kaltman JR, Rhodes LA, Wieand TS, Ennis JE, Vetter VL, Tanel RE. Slow pathway modification for atrioventricular nodal reentrant tachycardia. *American Journal of Cardiology*. 2004;94:1316–9.
16. Lesh MD, Van Hare GF, Fitzpatrick AP, Griffin JC, Chu E. Curing reentrant atrial arrhythmias. Targeting protected zones of slow conduction by catheter ablation. *Journal of Electrocardiology*. 1993;26:194–203.
17. Vos P, Pulles-Heintzberger CF, Delhaas T. Supraventricular tachycardia: An incidental diagnosis in infants and difficult to prove in children. *Acta Paediatrica*. 2003;92:1058–61.
18. Grossman VGA. An easy-to understand look at pediatric paroxysmal supraventricular tachycardia. *Journal of Emergency Nursing*. 1997;23:367–74.
19. Sanatani S, Hamilton RM, Gross GJ. Predictors of refractory tachycardia in infants with supraventricular tachycardia. *Pediatric Cardiology*. 2002;23:508–12.
20. Perry JC. Supraventricular tachycardia. In: Garson A, Bricher JT, Fisher DJ, Neish SR (editors), The science and practice of pediatric cardiology. William and Wilkins. 1997;2059–101.
21. Cappato R, Schluter M, Weiss C, Antz M, Koschyk DH, Hofmann T, et al. Radiofrequency current catheter ablation of accessory atrioventricular pathways in Ebstein's anomaly. *Circulation*. 1996;94:376–83.
22. Khositseth A, Danielson GK, Dearani JA, Munger TM, Porter CJ. Supraventricular tachyarrhythmias in Ebstein anomaly: Management and outcome. *Journal of Thoracic Cardiovascular Surgery*. 2004;128:826–33.
23. Okishige K, Azegami K, Goseki Y, Ohira H, Sasano T, Kamashita K, et al. Radiofrequency ablation of tachyarrhythmias in patients with Ebstein's anomaly. *International Journal of Cardiology*. 1997;60:171–80.
24. Reich JD, Auld D, Hulse E, Sullivan K, Campbell R. The Pediatric Radiofrequency Ablation Registry's experience with Ebstein's anomaly. Pediatric Electrophysiology Society. *Journal of Cardiovascular Electrophysiology*. 1998;9:1370–7.
25. Snyder CS, Fenrich AL, Friedman RA, Rosenthal G, Kertesz NJ. usefulness of echocardiography in infants with supraventricular tachycardia. *American Journal of Cardiology*. 2003;91:1178–83.
26. Liberman L, Pass RH, Starc TJ. Optimal surface electrocardiogram lead for identification of the mechanism of supraventricular tachycardia in children. *Pediatric Emergency Care*. 2008;24:28–30
27. Wellens HJ, Bar FW, Lie KI. The value of the electrocardiogram in the differential diagnosis of a tachycardia with a widened QRS complex. *American Journal of Medicine*. 1978;64:27–33.
28. Walsh EP, Saul P, Hulse JE, Rhodes LA, Hordof AJ, Mayer SE, et al. Transcatheter ablation of ectopic atrial tachycardia in young patients using radiofrequency current. *Circulation*. 1992;86:1138–46.
29. Kugler JD, Danford DA, Houston KA, Felix G. Pediatric radiofrequency catheter ablation registry success, fluoroscopy time, and complication rate for supraventricular tachycardia: Comparison of early and recent eras. *Journal of Cardiovascular Electrophysiology*. 2002;13:336–41.
30. Saul JP, Hulse JE, De W, Weber AT, Rhodes LA, Lock JE, et al. Catheter ablation of accessory atrioventricular pathways in young patients: Use of long vascular sheaths, the transseptal approach, and a retrograde left posterior parallel approach. *Journal of American College of Cardiology*. 1993;21:571–83.
31. Danford DA, Kugler JD, Deal BJ, Case C, Friedman RA, Saul JP, et al. The learning curve of radiofrequency ablation of tachyarrhythmias in pediatric patients. *American Journal of Cardiology*. 1995;75:587–90.
32. Bhatia A, Sra J, Dhala A, Blanck Z, Deshpande S, Baig S, et al. Radiofrequency catheter ablation of atrial tachycardia using noncontact computerized mapping system. (abstract). Circulation, 2000;102, II–527.
33. Jais P, Haissaguerre M, Shah DC, Takahashi A, Hocini M, Lavergne T, et al.Successful irrigated-tip catheter ablation of atrial flutter resistant to conventional radiofrequency ablation. *Circulation*. 1998;98:835–8.
34. Tracy CM, Swartz JF, Fletcher RD, Hoops HG, Solomon AJ, Karasik PE, et al. Radiofrequency catheter ablation of ectopic atrial tachycardia using paced activation sequence mapping. *Journal of American College of Cardiology*. 1993;21:910–7.
35. Triedman JK, Jenkins KJ, Colan SD, Saui JP, Walsh EP. Intra-atrial reentrant tachycardia after palliation of congenital heart disease: Characterization of multiple macroreentrant circuits using fluoroscopically based three-dimensional endocardial mapping. *Journal of Cardiovascular Electrophysiology*. 1997;18:259–270.
36. Schaffer MS, Gow RM, Moak JP, Saul JP. Mortality following radiofrequency catheter ablation (from the Pediatric Radiofrequency Ablation Registry). Participating members of the Pediatric Electrophysiology Society. *American Journal of Cardiology*. 2000;86:639–43.
37. Schaffer MS, Silka MJ, Ross BA, Kugler JD, participating members of the Pediatric Electrophysiology Society. Inadvertent atrioventricular block during radiofrequency catheter ablation: Results of the Pediatric Radiofrequency Ablation registry. *Circulation*. 1996;95:3214–20.
38. Kugler JD, Danford DA, Houston K, Felix G. Radiofrequency catheter ablation for paroxysmal supraventricular tachycardia in children and adolescents without structural heart disease. *American Journal of Cardiology*. 1997;80:1438–43.
39. Seixo F, Rossi R, Adracao P, Cavaco D, Santos KR, Morgado FB, et al. Percutaneous Catheter Ablation of Arrhythmias in Children. *Revista Portuguesa de Cardiologia*. 2008;27:1419–26.