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Ten-year Experience of Radiofrequency Catheter Ablation of Accessory Pathways in Children and Young Adults

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Abstract Transcatheter radiofrequency ablation of supraventricular tachycardia was first introduced in 1987. The procedure is now well-accepted as primary treatment for supraventricular tachycardia in paediatric patients. In this report we describe our experience of radiofrequency ablation of accessory pathway mediated supraventricular tachycardia in the past 10 years. From 1994 to 2005, 121 procedures of radiofrequency ablation of accessory pathway were performed on 103 children and young adults aged 4.3 to 24.7 years. Ninety-three patients (90.3%) had one pathway and 10 (9.7%) had 2 pathways. Forty-four percent of all accessory pathways were associated with Wolff-Parkinson-White syndrome. There were 73 (65.2%) left-sided accessory pathways and 39 (34.8%) right-sided accessory pathways. One hundred and three (92%) accessory pathways were successfully ablated. Successful rate of left-sided accessory pathway ablation was higher than the right-sided accessory pathway (97.3% vs. 82.1%, p=0.005). Two patients (1.9%) developed major complications: one transient second degree and one permanent complete heart block who required permanent pacing. Recurrence after first successful radiofrequency ablation was 10.4% (9/86). Seventeen procedures (14%) were performed for failed first radiofrequency ablation or recurrence. On follow-up 90.3% of all patients remained asymptomatic. Our experience indicated that radiofrequency ablation is a safe and effective treatment for accessory pathway mediated supraventricular tachycardia in children and young adults.

Key words Accessory pathways; Children; Radiofrequency ablation; Supraventricular tachycardia

Introduction

Supraventricular tachycardia (SVT) is the most common tachyarrhythmia in children.[1] The incidence of SVT is estimated to be between one in 250 to one in 1000 children.[2] There are three important mechanisms of SVT: accessory pathway (AP) mediated atrio-ventricular reentry tachycardia (AVRT), atrio-ventricular nodal reentry tachycardia and ectopic atrial tachycardia. In the study by Ko et al, AVRT is the commonest cause of SVT in children, accounting for about 73% of all cases.[3]

Previously surgical division of AP by cardiac operation was required to achieve cure for patients with drug refractory AVRT. However the complications associated with surgical treatment ranged from 5% to 20%.[4] In 1987 successful transcatheter radiofrequency ablation of SVT in human was first reported.[5] Since then, it is now widely accepted as a curative treatment for SVT. In 1994, radiofrequency ablation (RFA) became available for management of paediatric cardiac arrhythmias in our institute. In this report, we reviewed the efficacy and safety of this procedure for children and young adults with AVRT.

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Patients and Methods

Between May 1994 and February 2005, a total of 121 RFA were performed in children and young adults with accessory pathway mediated SVT in our unit. The clinical and electrophysiological data of these cases were analysed. The patients were referred to our unit because of documented SVT or undiagnosed palpitation. Treatment strategy was individualised according to the symptoms. Patients were considered for RFA if 1) SVT not satisfactorily controlled by anti-arrhythmic agents, 2) drug treatment not preferred despite recurrent symptoms and 3) potential risk of pre-excitation not accepted by the patients.

Anti-arrhythmic agents were discontinued at least 72 hours before the procedure. All procedures were performed in the fasting state. Majority of patients were sedated with intravenous midazolam and/or ketamine. For very young patients and those having difficulties with sedation, the procedure was performed under general anaesthesia. Before RFA, electrophysiologic study (EPS) was performed. Four electrode catheters were positioned at the right ventricular apex, His bundle area, coronary sinus and right atrium respectively (Figure 1). Twelve-lead surface electrocardiograms (ECG) were recorded, along with bipolar intracardiac electrograms. Standard protocols for atrial and ventricular extrastimulus testing were performed. If reentrant tachycardia was not induced at the baseline state, an infusion of isoproterenol was used. After electrophysiological evaluation, a steerable radiofrequency (RF) catheter was used for detailed mapping and ablation. For left-sided AP ablation, the RF catheter was advanced into the left ventricle retrogradely via the femoral artery or transseptally through the atrial septum. The RF catheter was positioned at the mitral annulus for mapping. As for right-sided APs, they were approached through the femoral vein or right internal jugular vein. The ablation catheter was positioned at atrial aspect of the tricuspid annulus. The catheter positions were monitored using biplane fluoroscopy with standard right anterior oblique and left anterior oblique views. Systemic heparinization was performed before insertion of catheters into the left ventricle. The AP was localised by the shortest atrio-ventricular (AV) or ventriculo-atrial (VA) interval during atrial pacing, ventricular pacing or SVT. After precise mapping of AP, RF energy was delivered to the target site with a temperature-controlled generator for 30-60 seconds via the RF catheter. The preset temperature was 60°C for left-sided AP and 70-80°C for right-sided AP. Ablation of right-sided AP required a higher pre-set temperature because of relatively unstable catheter position. Additional application of RF energy between one to three minutes was given after initial successful ablation to reduce recurrence of AP conduction. The procedure was considered successful if there was no electrophysiological evidence of accessory pathway conduction during a 30-minute period of post ablation testing, with or without isoproterenol infusion.

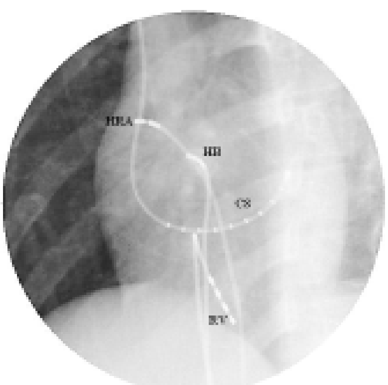

Figure 1 The left anterior oblique view showed the mapping catheters placed at the high right atrium (HRA), His bundle (HB), coronary sinus (CS) and right ventricle (RV) during an electrophysiological study.

After the procedure, patient was observed overnight. Patients underwent RFA of left-sided pathway would receive low dose aspirin therapy for three months to prevent thrombo-embolism. All patients were seen at two weeks, 3 months, 6 months, and then at 12-month interval after the procedure. During follow-up, ECG was performed and patients were questioned about symptoms of recurrent SVT. Recurrence was based on documentation of pre-excitation or SVT by 12-lead ECG, event recorder or 24-hour Holter monitoring.

Statistical Methods

Continuous variables were expressed as mean (±standard deviation). Categorical variables were analyzed by Chi-square test. One-way analysis of variance was utilised comparing means between subgroups. Statistical analysis was performed with SPSS version 11.0 (SPSS Inc., Chicago, United States). A cut-off *P* value for statistical significance was taken as 0.05.

Results

Patient Characteristics

One hundred and twenty-one RFA were performed on

103 patients (male 54 and 49 female). Their mean age at the time of initial RFA was 12.8±3.9 years (range 4.3 to 24.7 years) (Figure 2). Their mean body weight was 44.4±17.4 kg (range 16.0 to 119.0 kg) (Figure 3). All except one patient had symptomatic palpitations, and 2 experienced syncope during the attacks. The asymptomatic patient was noted to have pre-excitation on ECG during pre-operative work-up for spinal surgery. RFA was considered before the orthopaedic surgery to prevent development of SVT intra- or post-operatively.

Before the procedure, eighty-four (81.6%) patients were treated with various anti-arrhythmic agents, including digoxin, propranolol, metoprolol, atenolol, sotalol, verapamil, flecainide, propafanone and amiodarone. Some patients had trial of up to four anti-arrhythmic agents that were ineffective or partially effective in preventing the recurrence of SVT. Ninety-eight patients (95.1%) had normal structured heart. Five patients had structural heart disease: coronary sinus diverticulum (n=1), Ebstein anomaly of tricuspid valve (n=1), coronary sinus diverticulum and small secundum atrial septal defect (n=1), mild aortic regurgitation (n=1) and complex cyanotic heart disease (n=1).

Pathway Locations

Ninety-three patients (90.3%) had one AP and 10 (9.7%) had two APs. Five patients had two concomitant right-sided APs while four patients had two concomitant left-sided APs. One patient has one left-sided free wall AP and one right-sided mid-septal AP. Ablation of the mid-septal AP was not attempted because the potential risk of complete heart block. Among all the 112 targeted APs, 49 (43.8%) were manifest pathway with pre-excitation in the resting ECG. The remaining 63 (56.2%) were concealed APs. Seventy-three (65.2%) APs were left-sided whereas 39 (34.8%) were right-sided. The distribution of pathway location is illustrated in Figure 4. Two patients had right-sided slow antegrade conducting AP (Mahaim fibre). They presented as wide-QRS complex antidromic tachycardia, that mimicked ventricular tachycardia.

Successful Rate and Recurrence

Successful ablation after the first RFA was achieved in 96 (85.7%) APs. The initial successful rate for left-sided APs was significantly higher than that of the right side (93.2% vs. 71.8%, P=0.002). Success or failure of RFA was not related to whether the pathway was manifest or concealed. The mean procedural and fluoroscopy time were 195.8±75.6 minutes (range 45 to 400 minutes) and 50.8±42.8 minutes (range 5.8 to 180 minutes) respectively. Ablation of a right-sided AP was associated with significantly longer procedural and fluoroscopy time. Recurrence rate was also significantly higher in right-sided APs. Comparison of successful rates and other parameters between left-sided and right-sided pathways are shown in Table 1.

Among the 17 patients who failed the first attempt, ten had undergone a second ablation. Redo ablations were successful in eight (80%) procedures. Documented recurrence of AP conduction occurred in 9 patients (8.7%). Seven opted for a second procedure. All these redo ablations were successful. One patient with a right free wall manifest

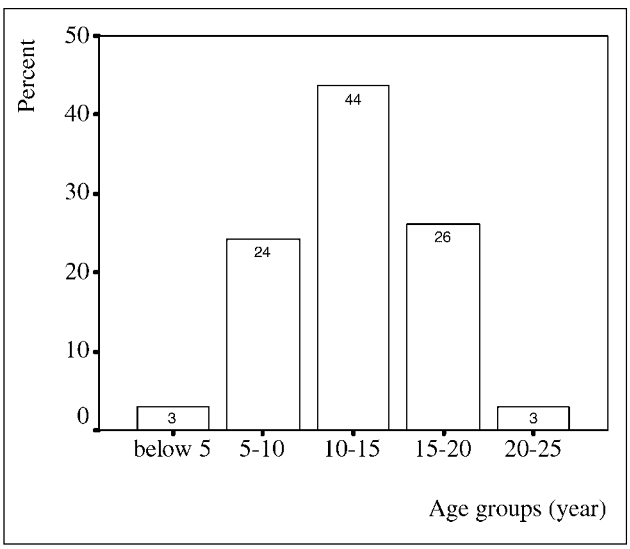

Figure 2 Distribution of age of patients.

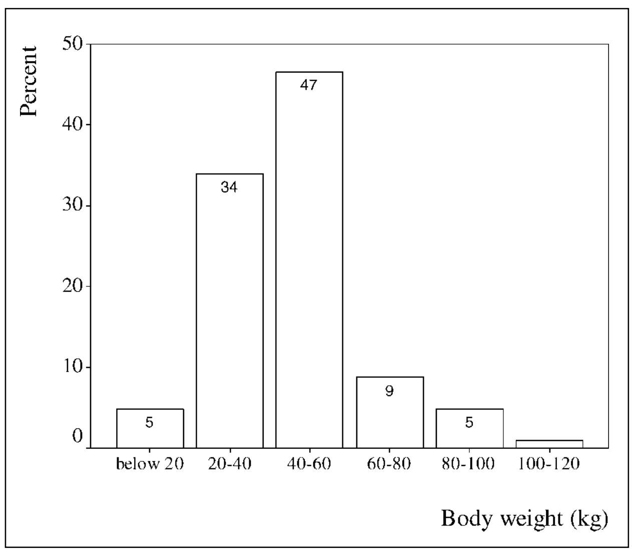

Figure 3 Distribution of body weight of patients.

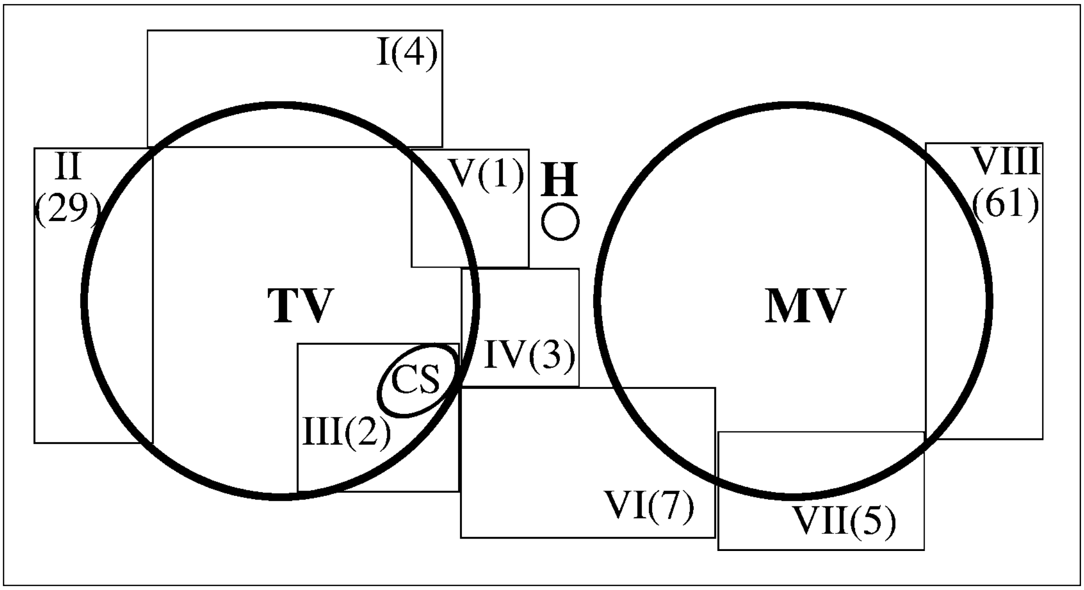

Figure 4 The distribution of accessory pathways. The diagram illustrates the right and left AV grooves, around the tricuspid and mitral valve annuli, respectively, as projected in the left anterior oblique view under fluoroscopy. The AV grooves are divided into several zones. The value in the parenthesis represents the number of pathway in that zone. MV=Mitral valve; TV=tricuspid valve; H=His bundle; CS=coronary sinus; zone I=right anterior; zone II=right lateral; zone III=right posteroseptal; zone IV=right midseptal; zone V=right anteroseptal; zone VI=left posteroseptal; zone VII=left posterior; zone VIII=left lateral.

Table 1 Comparison of outcome and procedural-related parameters of left and right-sided pathways

	Right-sided pathway	**Left-sided pathway**	***P*-value**
Initial successful rate (%)	71.8	93.2	0.002
Final successful rate (%)	82.1	97.3	0.005
Fluoroscopy time (minute)	71.0±45.3	37.4±37.6	<0.001
Procedural time (minute)	233.2±66.2	168.0±67.2	<0.001
Recurrence rate (%)	17.9%	4.1%	0.02

AP had recurrence despite three successful RFA. Pre-excitation re-emerged three months after the third RFA. One hundred and three (92% APs) were successfully ablated. The overall successful pathway ablation rate including re-do procedure, was 92%. The procedural successful rate was 85.1% in our series. The procedural successful rate for the left-sided AP is significantly higher than that of the right-sided AP (93.2% vs. 71.8%, P=0.001).

Four out of the five patients (80%) with structural heart disease have successful RFA. Three patients had their APs abolished in one attempt. The first RFA was unsuccessful in the patient with Ebstein anomaly who had a manifest right free wall AP. The redo RFA was successful but SVT recurred on the following day. The third procedure was successfully performed four days later and there was no more recurrence on follow-up. The patient with complex cyanotic heart disease had a right free wall AP. Due to the complexity of the cardiac anomaly, further RFA was not attempted after the first unsuccessful RFA.

Complications

One patient developed persistent complete heart block after successful RFA for a mid-septal AP. She subsequently had a permanent pacemaker implantation. Another patient who had a left postero-septal AP, developed transient second-degree heart block during the procedure but recovered spontaneously. There was no procedure-related mortality.

Follow-up

The mean follow-up duration was 43.5±34.6 months. Ninety patients (87.3%) showed no SVT or recurrence of pre-excitation. Two patients had recurrence of pre-excitation without SVT attacks. One had re-emergence of pre-excitation few hours after RFA whereas another one had it three months later. One patient had failed RFA with persistence of pre-excitation but she never had documented SVT thereafter for nine years. Hence, ninety percent of our patients were asymptomatic at the time of our study. Ten patients remained symptomatic and four of them required anti-arrhythmic agents. The clinical course of our study subjects was summarised in Figure 5.

Discussion

An accessory pathway is a microscopic, electrically conducting tract connecting atrium to ventricle at the AV groove. Manifest pathways are those capable of antegrade conduction from atrium to ventricle, resulting in ventricular pre-excitation. The ECG findings of a delta wave, short PR interval and wide QRS duration are the hallmarks of ventricular pre-excitation. On the contrary, a concealed pathway only conducts retrogradely from ventricle to atrium with no pre-excitation on ECG. The presence of an AP is a potential mechanism to develop AVRT. During orthodromic AVRT, antegrade conduction occurs over the AV node to the ventricle, with retrograde conduction returning to the atrium via the AP. In antidromic AVRT, conduction proceeds in the reverse direction, with antegrade conduction

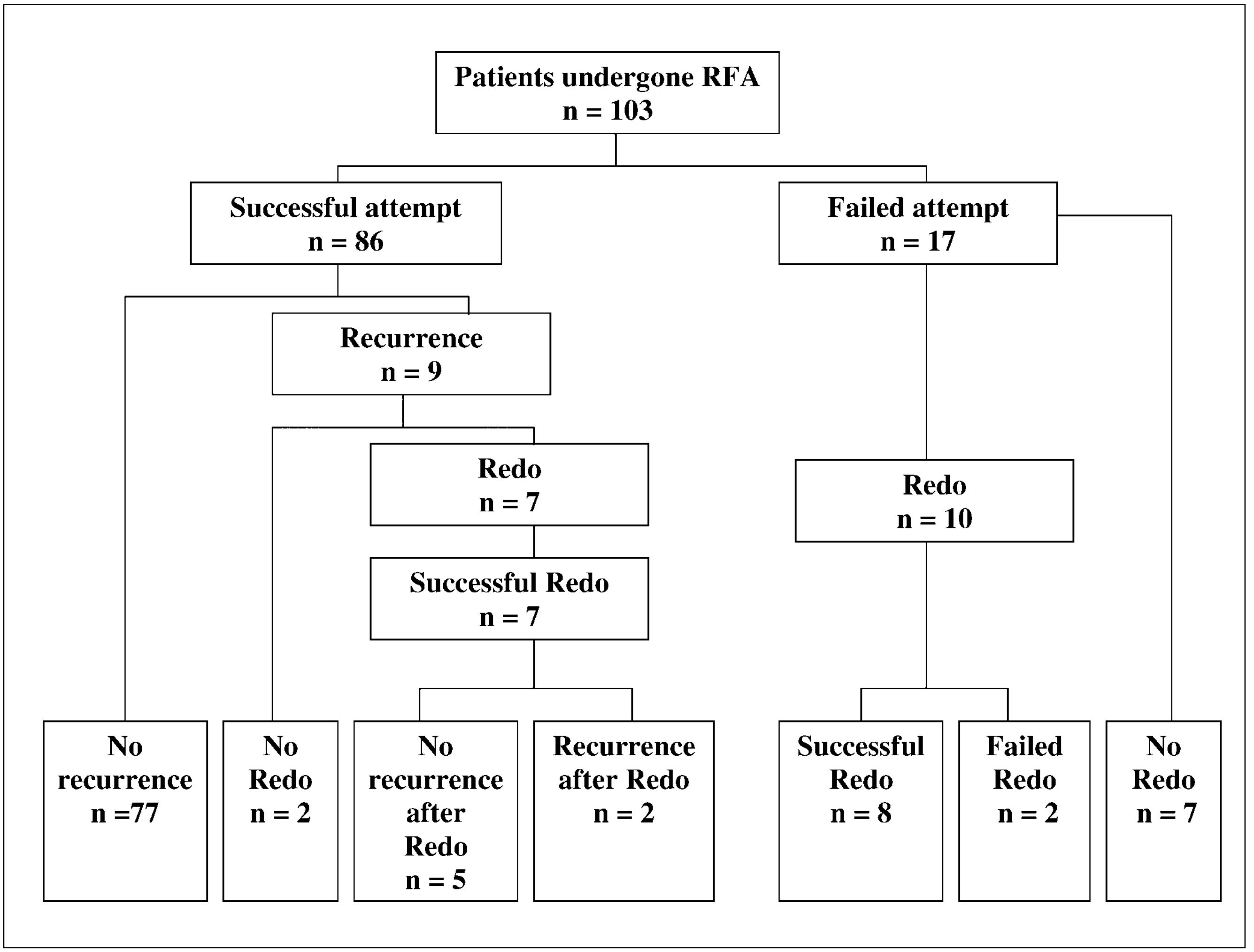

Figure 5 Summary of clinical courses of all subjects.

occurs over the AP to the ventricle, and retrograde conduction returning to the atrium via the AV node. In patient with manifest pathway, atrial fibrillation with rapid conduction via the AP to the ventricle may result in ventricular fibrillation and sudden death.

The management of AVRT in children depends on patient's age and symptoms. AVRT that occurs in infancy may remit spontaneously, although it frequently recurs in later childhood. If SVT persists beyond the age of 5 years, seventy-eight percent of them will continue to experience SVT.[6] For infants with SVT, medical therapy is still the first-line treatment in preventing recurrence. Beyond infancy, short duration of SVT is usually well tolerated, therefore, patients with infrequent symptoms can be managed conservatively. In the more symptomatic patients, anti-arrhythmic drugs may be effective to prevent recurrence. However, long term drug therapy is not welcomed by many patients because of side effects, inconvenience and problem of drug compliance. Before RFA was available, patients with severely symptomatic SVT required cardiac arrhythmia surgery to achieve cure.[7] In the early 1980s transcatheter direct-current shocks was also used for ablation. However the high morbidity of these two approaches were well recognised. RF energy is alternating electrical current in the radiofrequency range. When applied via a RF catheter to the substrate of cardiac arrhythmia, the heating effect of RF energy coagulates the tissue at a local temperature of approximately 50°C. It has been shown that RFA has lower mortality and morbidity rates and also more cost-effective than surgery or long term drug therapy.[8]

Although the efficacy and safety of RFA for treating SVT in children has been reported, the age and body size limits for this invasive procedure is not well-defined. Some paediatric electrophysiologists suggest that RFA should be avoided in children younger than 5 years of age, unless the SVT is resistant to medical therapy.[9] At present most cardiologists agree that if syncope develops during SVT or if antegrade conduction through the AP is very fast, RFA should be considered as first line therapy.[9] On the other hand, there is divergence of opinion regarding the use of RFA for asymptomatic pre-excitation.[9]

RFA can be performed with a high degree of success in patients with AVRT. In 2002 the Pediatric Radiofrequency Ablation Registry reported a procedural successful rate of 91.4% for AVRT ablation.[10] The successful rates for the left-sided AP and right-sided AP were 95.2% and 88.0% respectively.[10] In our series, we have a similar procedural successful rate for left-sided AP (93.2%) but a lower rate for right-sided AP (71.8%). Successful RFA of AP not only depends on operator's experience, but also on the location of the substrate. Ablation of an AP requires stable catheter tip contact to allow continuous energy delivery. This is generally easier to achieve with left sided pathways because the catheter tip can be wedged below the mitral annulus from the left ventricular approach. As for right-sided AP, stable catheter position is more problematic when they are approached from the right atrium onto the tricuspid annulus directly.[11] Ablation of right-side AP is technically more demanding as evidenced by longer fluoroscopy and procedural times in our series.

The Pediatric Radiofrequency Ablation Registry in 2002 reported 77% of the APs were free from recurrence three years after the procedure.[10] The freedom from recurrence for left free wall pathways was significantly higher.[10] Recurrence occurred in 8.9% of our patients and 17.9% of all right-sided APs. Wu et al. reported a similar recurrence rate of 11.9% in a single centre study.[12] That study also showed a higher recurrence rate for right-sided APs comparing to left-sided APs (21.7% vs. 5.6%).[12] The difference in the recurrence can be explained by the differences in the effectiveness of energy delivery and tissue heating as noted above. Our results at mid-term follow-up (43.5±34.6 months) were excellent in this series. Ninety percent of patients were asymptomatic during follow-up. Two patients had recurrence of pre-excitation without SVT attacks. One patient had failed RFA with persistence of pre-excitation but no more documented SVT again. In these three patients, RFA might already significantly modify the conduction properties of the APs so that they could not sustain AVRT.

The safety of radiofrequency ablation of AP has been well-established.[10] Mortality associated with paediatric RFA is about 0.22%.[13] Death was related to myocardial perforation, coronary or cerebral embolism, and ventricular arrhythmia. Identified risk factors include underlying heart disease, lower body weight, greater number of radio-frequency energy applications and left-sided procedures.[13]

The overall major complication rate for paediatric RFA was 3%.[10] Ablation of pathways adjacent to AV node and His bundle, for example the mid-septal AP, is associated with high risk of heart block.[14,15] In our series, permanent complete heart block occurred in one patient after ablation of a mid-septal AP. This represented 0.8% of all 121 RFA, comparable to the published data of 0.7%.[14] Other major complications reported in the literature included cardiac perforation/pericardial effusion, brachial plexus injury, pneumothorax and thrombo-embolism.

Although the incidence of acute complication related to RFA is very low, the long term effect of tissue scarring by RF energy to immature myocardium is unknown. One animal study demonstrated the size of the scar at the ventricular myocardium after RFA increased with age.[16] Also the potential for RF energy to damage adjacent coronary artery should not be ignored.[17,18] There are case reports of coronary stenosis or occlusion after RFA.[19,20] In adult the risk of coronary artery stenosis after RFA has been shown to be low.[21] However in small child the proximity of coronary artery at the atrio-ventricular groove to the targeted AP is always a concern when RF energy is applied. Until results of longer term follow-up are available, a cautious approach of RFA in small child should be adopted. Prolonged radiation exposure during RFA is also a risk for long term complication. It has been estimated that for every 60 minutes of fluoroscopy, the mean total lifetime excess risk of a fatal malignancy was 0.03%.[22] The risk of severe hereditary effects was estimated to be less than 1 per million cases for 60 minutes of fluoroscopy.[22] Although the risk is small every effort should be made to minimise the radiation exposure to young patients during RFA.

Conclusion

Our results confirmed that radiofrequency catheter ablation of accessory pathways in children and young adults, as an alternative to long term medication, is effective and safe. But in view of the occasional serious complications and the lack of really long-term data of potential adverse effects on immature myocardium, the procedure should be considered only in children with moderate or severe symptoms.

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