

The Efficacy and Safety of Radiofrequency Catheter Ablation for Cardiac Arrhythmias in Pediatric Patients

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ABSTRACT

Background: We aimed to evaluate the acute and long-term efficacy and safety of radiofrequency catheter ablation (RFCA) in Chinese pediatric patients with arrhythmias.

Methods: We gathered clinical data from pediatric patients who underwent RFCA in several large medical centers in China between 2000 and 2019.

Results: A total of 4,622 different substrates in 4,622 patients were ablated, with the majority consisting of supraventricular tachycardia (N = 3,831, 82.9%) and ventricular arrhythmias (VAs) (N = 791, 17.1%). The majority of supraventricular tachycardia (SVT) consists of atrioventricular reentry tachycardia (AVRT) (N = 2,492, 65.0%) and atrioventricular nodal reentry tachycardia (AVNRT) (N = 1,075, 28.1%). The accessory pathway location was left-sided in 1,237 (49.7%) and right-sided in 1,251 (50.3%) of the 2,488 pathways. The VAs consist of premature ventricular contraction (PVC) (N = 597, 75.5%) and ventricular tachycardia (VT) (N = 194, 24.5%). The duration of follow-up ranged from 1 month to 1 year. The overall acute/long-term success rate of RFCA was 96.4%/92.2%, AVRT 97.8%/93.5%, AVRT 99.3%/95.0%, PVC 98.1%/92.2%, and VT 81.3%/75.2%. Serious complications occurred in 29 patients (0.6%).

Conclusions: This present study shows that RFCA is effective and safe in the treatment of arrhythmias in Chinese pediatric patients, with a high success rate exceeding 90%, low recurrence rate, and significantly reduces the risk of complications. The success rate of left-sided pathway ablation is slightly higher than that of the right-sided pathway. There is no difference in the success rate of RFCA among children of different ages. It could be the first-line therapy in the majority of pediatric patients with SVT and/or VAs.

INTRODUCTION

Radiofrequency catheter ablation (RFCA) has been used for the treatment of arrhythmias in children since 1991 [Walsh 1991]. Both retrospective and prospective studies have showed that RFCA is an effective and safe way of arrhythmia treatment in pediatric patients with good efficacy [Calkins 1999; Van 2004; Lenarczyk 2009]. Recent studies have shown improved success rate and low complications by using updated techniques such as 3-dimensional mapping and navigation system and cryogenic energy [Kubus 2014; Ceresnak 2015]. RFCA nowadays is considered the standard therapy for the majority of pediatric patients with supraventricular tachycardia (SVT). Although there are many single center and multicenter studies on radiofrequency ablation of arrhythmias in children, such data is less in China. The aim of this study was to evaluate the efficacy and safety of RFCA in the treatment of arrhythmias in pediatric patients in China.

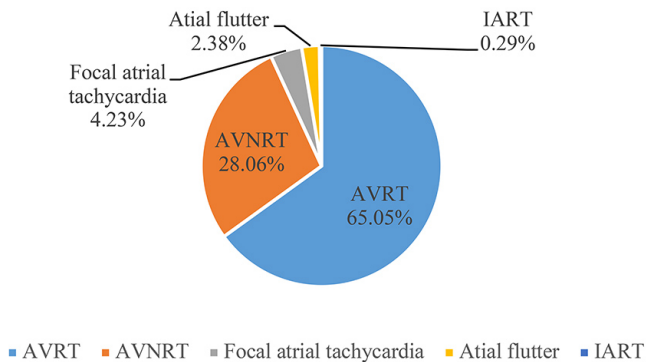
METHODS

We gathered clinical data from pediatric patients <18 years of age who underwent RFCA in several large medical centers in China between 2000 and 2019. Data included age, gender, type of arrhythmia, acute success, duration of follow up, long-term success, complications, and the presence of congenital heart disease. We excluded patients who were unwilling to receive follow up. The RFCA indications referred to the expert consensus on RFCA in children [Friedman 2002]. A total of 4,622 ablation procedures were performed in 4,622 patients (2,700 male; 1,922 female) <18 years old. The age at first ablation was 7.8 years \pm 3.7 years. The weight of patients at ablation was 29.7 kg \pm 5.5 kg. Diagnostic and ablation catheters used 4-6F and 5-7F, according to body size. For the substrate on the left side of the heart, retrograde approach or transseptal puncture was used. The evaluation of ablation endpoint is the same as the method reported in other study [Friedman 2002]. The Ensite Array, Ensite NavX or Carto system and general temperature-controlled ablation catheter or cold saline perfusion ablation catheter were used. The duration of follow up ranged from 1 month to 1 year. Recurrence was defined as one or more of the following: symptoms of discomfort highly suggestive of recurrence and documentation of original arrhythmia. Acute success was defined for

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The proportion of different types of supraventricular tachycardia
 AVRT: atrioventricular reentry tachycardia, AVNRT: atrioventricular node reentry tachycardia, IART: intra-atrial reentry tachycardia.

each patient as elimination of inducible tachycardia in the electrophysiology lab and absence of tachycardia for 24 hours after radiofrequency ablation. Long-term success was defined as each patient living with no evidence of recurrent symptomatic arrhythmia within the follow-up interval. No patient was lost during the follow-up period.

Statistical analysis: Continuous data were expressed as mean \pm standard deviation. Difference in proportions between 2 groups were tested by the χ^2 test. All statistical tests were two-sided, and a value $P < .05$ was regarded as significant. All statistical analysis was performed using SPSS 20.0 software.

RESULTS

Substrates: A total of 4,622 different substrates in 4,622 patients were ablated with the majority consisting of SVT ($N = 3,831$, 82.9%) and ventricular arrhythmias (VAs) ($N = 791$, 17.1%) (Table 1)

The majority of SVT consists of atrioventricular reentry tachycardia (AVRT) ($N = 2,492$, 65.0%) and atrioventricular nodal reentry tachycardia (AVNRT) ($N = 1,075$, 28.1%). The accessory pathway location was left-sided in 1,237 (49.7%) and right-sided in 1,251 (50.3%) of the 2,488 pathways. Other SVT included focal atrial tachycardia ($N = 162$, 3.5%), atrial flutter ($N = 91$, 2%), and intra-atrial reentry tachycardia ($N = 11$, 0.2%) (Figure). The VAs consist of premature ventricular contraction (PVC) ($N = 597$, 75.5%) and ventricular tachycardia (VT) ($N = 194$, 24.5%). There were 455 VAs originated from the left side of the heart and 351 originated from the right side of the heart. Congenital heart disease (CHD) was present in 61 patients; the most common structural defects were atrial septal defect ($N = 19$), ventricular septal defect ($N = 16$), tetralogy of Fallot ($N = 7$), Ebstein anomaly ($N = 6$), dilated cardiomyopathy ($N = 4$), patent ductus arteriosus ($N = 4$), congenitally corrected transposition of great arteries ($N = 2$) and double outlet right ventricle ($N = 2$).

Acute and long-term success: The acute and long-term success rate of radiofrequency ablation for different types of arrhythmias are shown

Table 1. Patient characteristics

Baseline data	Total
Patients	4622
Gender	2700M, 1922F
Weight (kg) (mean \pm s.d.)	29.7 \pm 5.5
Age of procedure (mean \pm s.d.)	7.8 \pm 3.7
Arrhythmogenic substrates	4622
SVT	3831
VAs	791
CHD	61

AVRT: atrioventricular reentry tachycardia; AVNRT: atrioventricular node reentry tachycardia; VAs: ventricular arrhythmias; IART: intra-atrial reentry tachycardia; CHD: congenital heart disease

in Table 2. The overall acute/long-term success rate of radiofrequency ablation was 96.4%/92.2%, respectively, and the recurrence was 4.8%. Among the SVT, the most common arrhythmias were AVRT with an acute/long-term success rate of 97.8%/93.5%, respectively, and the recurrence was 3.4%. AVNRT with an acute/long-term success rate of 99.3%/95.0%, respectively, and the recurrence was 4.4%. Among 806 ablated ventricular arrhythmias, the acute/long-term success rate of VAs were 94.4% and 88.2%, respectively. The acute/long-term success rate of PVC and VT were 98.1%/92.2%, 81.1%/75.3%, and the recurrence were 5.4% and 7.8%, respectively.

The acute and long-term success rate of radiofrequency ablation for specific accessory pathway localization and children of different ages is shown in Table 3. In the subgroup of left-sided and right-sided accessory pathways, acute and long-term success rates were 97.8%/96.9% and 93.5%/89.8%, respectively. In the subgroup of ages, the acute and long-term success rates for patients $<$ or $>$ 3 years old were 93.3%/87.6% and 97.1%/92.5%, respectively.

Complications: Serious complications occurred in 29 patients (0.6%). Complete atrioventricular block occurred in 7 patients. The block was transient in 1 patient and the remaining 6 patients needed to be implanted with pacemakers. Two-degree atrioventricular block occurred in 7 patients and medical intervention was not needed; all returned to normal during the follow-up period. Among the substrates, AVNRT was more likely to have complications, due to the special anatomy. Vascular-related complications occurred in 15 patients. Femoral artery pseudoaneurysm and arteriovenous fistula requiring surgical revision occurred in 6 and 4 patients, respectively. Five patients with venous thromboembolism needed to receive oral anticoagulants. All patients returned to normal after symptomatic treatment.

DISCUSSION

Radiofrequency catheter ablation has been used in children with supraventricular tachycardia since 1991 [Blafox

Table 2. Acute and long-term success of RFCA

Substrate	Acute success (%)	Long-term success (%)	P
All substrate	96.4	92.2	>.05
AVRT	97.8	93.5	>.05
AVNRT	99.3	95.0	>.05
VAs	94.4	88.2	>.05
Focal atrial tachycardia	82.1	69.1	>.05
Atrial flutter	95.6	85.7	>.05
IART	100	100	>.05

AVRT: atrioventricular reentry tachycardia; AVNRT: atrioventricular node reentry tachycardia; VAs: ventricular arrhythmias; IART: intra-atrial reentry tachycardia

1991]. RFCA of SVT and VAS in children is the recommended treatment for patients with severe symptoms, repeated recurrence, drug refractoriness and risk of sudden cardiac death [Rodriguez 1997; Brugada 2013]. This procedure has become first-line treatment for most patients with SVT, which can eliminate symptoms and improve the quality of life [Strieper 2010]. RFCA showed favorable efficacy and safety in patients with significant clinical symptoms and/or drug-refractory arrhythmias [Blaufox 2005; Johnsrude 2008]. For smaller children <18 months, RFCA also showed good efficacy without increasing the risk of complications [Blaufox 2001].

The aim of this study was to analyze the main types of arrhythmias, efficacy, and safety of RFCA in children in China to better supply ablation data from a certain area. The most important criteria for RFCA in pediatric patients are success rates, major complications, and a low rate of tachycardia recurrence. The present study showed that the overall success rate of RFCA was 96.4%, slightly higher than that of other pediatric reports (95.7%-96.0%) [Calkins 1999; Van 2004]. In accordance with other studies, the AVRT and AVNRT were the most common arrhythmogenic substrates [Lenarczyk 2009; Lee 2010]. The acute and long-term success rate of AVRT in our study corresponds to other pediatric reports [Campbell 2002]. In patients with accessory pathways, higher efficacy has been noted for the left-sided pathway than the right-sided pathway. The acute ablation success rate of AVNRT was 99.3%, which was slightly higher than that of other pediatric reports [Kubus 2014]. Atrioventricular block was the most common complication due to AVNRT ablation, therefore, when performing this procedure, more caution is needed and using short-term multiple discharge can reduce the probability of damage to the atrioventricular node. VT may cause significant morbidity and rarely mortality in the young [Stevenson 2007]. Elimination of the anatomic substrate by RFCA may thus offer a treatment option for symptomatic patients. In a study, reported ablation of VT in young patients achieved an acute success rate of 60% [Morwood 2004], which significantly is lower

Table 3. Acute and long-term success of RFCA for special location of AVRT and patients of different ages

Success (%)	Acute success	Long-term success
Left pathway	98.8	97.4
Right pathway	96.9	89.8
P value	>.05	>.05
<3 years old	93.3	87.6
>3 years old	97.1	92.5
P value	>0.05	>0.05

than the present study. Compared with VT, the acute and long-term success rate of RFCA for PVC was significantly higher, meanwhile, the recurrence rate remained low. It may be related to the complicated mechanisms of VT and difficulty of ablation. The acute ablation success rate of right ventricular outflow tract septum and left ventricular septum was the highest, followed by the free wall ventricular arrhythmias of right ventricular outflow tract. Three-dimensional cold saline perfusion ablation significantly can improve the success of ablation for PVC/VAs.

In the subgroup analysis, we explore the effect of age on RFCA and found that the acute and long-term success rate in patients > 3 years old is slightly higher than that of the patients < 3 years old, but it is of no statistical significance. (Table 3) The present study corresponds with other pediatric reports that showed no differences were found for success rates between infants (<18 months) and noninfants [Blaufox 2001].

The major concern regarding ablation in children is the risk of complications. Small children generally are at greater risk for the procedure complications [Lenarczyk 2009; Kugler 2010]. The risk of complications in the present study is about 0.6%, which is lower than other pediatric reports [Chiu 2009]. Most minor complications do not require treatment and can recover itself. Complete atrioventricular block was the most serious complication in the present study, of which 6 were treated with permanent pacemaker implantation. Other serious complications were recovered after symptomatic treatment. The occurrence of complications closely is related to the experience of the physician, and the increased experience can reduce the risk of complications.

There are several limitations to the study. First, the clinical data collected in this study span a relatively long time, and procedure-related variables such as operation proficiency, different mapping apparatus, size of catheter, and type of ablation energy may have been related to the outcome. Second, there are differences in the ablation schemes and proficiencies between different medical centers during the same period. Third, most of the duration of follow-up was less than 1 year, given the fact that certain kinds of arrhythmia showed late recurrence, a longer duration of follow-up in the future study is needed. Considering the large pediatric population in China, more and larger clinical studies are needed to further confirm the efficacy and safety of RFCA.

CONCLUSIONS

This present study shows that RFCA is effective and safe in the treatment of arrhythmias in Chinese pediatric patients, with a high success rate exceeding 90%, low recurrence rate, and it significantly reduces the risk of complications. The success rate of left-sided pathway ablation is slightly higher than that of the right-sided pathway. There is no difference in the success rate of RFCA among children of different ages. It could be the first-line therapy in the majority of pediatric patients with SVT and/or VAs.

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