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# Radiofrequency Ablation for Supraventricular Tachycardia in Children ≤ 15 kg Is Safe and Effective

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**Abstract.** Risks associated with radiofrequency ablation (RFA) have been reported to be increased in children ≤ 15 kg. We sought to compare the safety and efficacy of RFA in children < 15 kg with those between 15.1 and 20 kg. Clinical, electrophysiologic, and RFA data for all patients ≤ 20 kg who underwent RFA for supraventricular tachycardia between January 1994 and January 2003 were reviewed. Patients were divided into those ≤ 15 kg (group 1, $n = 25$) and those between 15.1 and 20 kg (group 2, $n = 44$). The two groups differed significantly in age and weight by design (group 1: mean weight, 11.9 ± 3.0 kg; age, 2.8 ± 1.9 years; group 2: weight, 18.0 ± 1.5 kg; age, 5.1 ± 1.1 years). There were no significant differences in other baseline characteristics except for incidence of structural heart disease (28% group 1 vs 7% group 2, $p < 0.01$). No significant differences in mechanism of tachycardia, arrhythmia cycle length, number of total and brief RFA applications, total RFA time, average and maximum RFA temperatures, total procedure duration, short-term success rate (96% group 1 vs 86% group 2, $p = 0.17$), long-term success rate (91% group 1 vs 89% group 2, $p = 0.76$), or major complications (8.0% group 1 vs 2.3% group 2, $p = 0.39$) were found. There were no procedure-related deaths in either group. These data suggest that, in two large volume electrophysiology centers, the procedural risks and outcomes of RFA are similar between patients weighing less than 15 kg and those between 15.1 and 20 kg.

**Key words:** Radiofrequency ablation — Supraventricular tachycardia

Radiofrequency ablation (RFA) has been demonstrated to be safe and effective when applied to pediatric patients [4, 15]. In many centers, RFA has become first-line therapy for supraventricular tachycardia (SVT) in adolescents with symptomatic tachycardia. Although RFA has been used to treat SVT in younger patients and infants, it has generally been reserved for patients refractory to maximal medical management [3, 6, 13, 14, 16, 17].

It has been reported that the risks of RFA are increased in children < 15 kg [9]. However, there are conflicting data on this issue [1]. It has been suggested that smaller patients are at increased risk for heart block [10], radiofrequency lesion extension [12], and injury to vascular structures, both cardiac and noncardiac [2].

Although the majority of infants with SVT can be managed medically, and the natural history of SVT in infants favors spontaneous resolution within 1 or 2 years, occasionally ablative therapy is necessary. Due to the rarity of the need to proceed with RFA in these patients, there are limited published data regarding infant RFA for SVT. This report summarizes our experience using RFA to treat SVT in infants and toddlers who were refractory to medical therapy and finds that RFA can be a safe and effective therapy in this group of patients.

## Methods

The RFA databases at the University of Michigan Congenital Heart Center and the University of Utah were queried for all patients ≤ 20 kg undergoing RFA for SVT between January 1994 and January 2003. The indication for RFA in children ≤ 20 kg was recurrent hemodynamically compromising SVT that was unable to be controlled with medical management including amiodarone or sotalol as well as a combination of a class Ic and III agent. The following patient data were gathered from hospital records: age, gender, weight, the presence of structural heart disease, SVT mechanism, accessory pathway location, catheter approach, SVT cycle length, number of RFA applications, number of brief (< 20 seconds) RFA

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**Table 1.** Baseline patient characteristics

| | Group I | Group II | Range | *p* |
|---|---|---|---|---|
| Age (years; mean ± s.d.) | 2.8 ± 1.9 | 5.1 ± 1.1 | 0.1 – 7.2 | < 0.001 |
| Weight (kg; mean ± s.d.) | 11.9 ± 3.0 | 18.0 ± 1.5 | 4.1 – 20.0 | < 0.001 |
| Gender | 8F, 17M | 24F, 20M | | 0.07 |
| Structural heart disease (%) | 7/25 (28%) | 3/44 (7%) | | < 0.01 |
| EKG with manifest accessory pathway (%) | 10/21 (48%) | 20/39 (51%) | | 0.79 |

**Table 2.** Electrophysiology study and radiofrequency ablation data

| | Group 1 | Group 2 | Range | *p* value |
|---|---|---|---|---|
| Sedation type (% general anesthesia) | 23/25 (92) | 42/44 (95) | | 0.56 |
| Accessory pathway location (% left-sided) | 13/25 (52) | 21/44 (48) | | 0.78 |
| RFA approach (% transseptal puncture) | 6/25 (24) | 15/44 (34) | | 0.27 |
| Tachycardia mechanism (% AVRT) | 19/25 (76) | 37/44 (84) | | 0.67 |
| Cycle length (msec) | 283 ± 48 | 307 ± 46 | 220-430 | 0.06 |
| No. of RFA applications | 7.0 ± 6.2 | 6.7 ± 6.4 | 1-28 | 0.83 |
| RFA total time (sec) | 143 ± 94 | 152 ± 148 | 2-786 | 0.79 |
| RFA average temperature (C) | 51.1 ± 4.1 | 50.2 ± 2.8 | 46-63 | 0.47 |
| RFA maximum temperature (C) | 62.6 ± 7.3 | 58.1 ± 7.1 | 48-75 | 0.08 |
| Total procedure time (min) | 219 ± 86 | 244 ± 77 | 110-495 | 0.22 |

RFA, radiofrequency ablation; AVRT, atrioventricular reentrant tachycardia.

applications, total RFA time, average and maximum RFA temperatures, total procedure time, short-term success, complications, duration of follow-up, and long-term success.

Patients were divided into two groups: group 1 ( ≤ 15 kg) and group 2 ( > 15 kg and ≤ 20 kg). Data were analyzed using the chi-square method for categorical variables and the *t*-test for continuous variables. A $p$ value of ≤ 0.05 was taken to denote a significant difference.

Short-term success was defined for each case as elimination of inducible tachycardia and preexcitation in the electrophysiology lab and absence of tachycardia and preexcitation for 24 hours post-RFA. Long-term success was defined for each patient by being alive with no evidence of recurrent symptomatic tachycardia at last follow-up. Complications were subdivided into major and minor categories.

Of the 63 patients reported in this review, 48 have previously been included in the reports of the Pediatric Radiofrequency Ablation registry [9, 10].

## Results

There were 25 cases among 23 patients in group 1 and 44 cases among 40 patients in group 2. Baseline characteristics for the two groups are shown in Table 1. The two groups differed significantly in age and weight by design. There were no significant differences in other baseline characteristics except for the incidence of structural heart disease (28% in group 1 vs 7% in group 2, $p < 0.01$). There were no significant differences between the groups in mechanisms of SVT.

Accessory pathway-mediated atrioventricular reentrant tachycardia (AVRT) was the predominant mechanism of tachycardia in both groups, accounting for 76% of cases in group 1 and 84% of cases in group 2. There were two cases (8%) of atrioventricular nodal reentrant tachycardia (AVNRT) in group 1 versus four cases (9%) in group 2. There was one case of ectopic atrial tachycardia (EAT) in each group.

Data gathered from the electrophysiologic study are shown in Table 2. There were no statistically significant differences between the groups in sedation type, tachycardia mechanism, pathway location, catheter approach, arrhythmia cycle length, number of RFA applications, number of brief RFA applications, total seconds of RFA, average RFA temperature, maximum RFA temperature, or total procedure duration. Access to the left atrium was required in approximately half the cases and was achieved via one of three approaches: through an existing atrial septal defect, transseptal puncture, or, in two cases in group 2, retrograde through the aortic arch.

Success rates and complication data are shown in Table 3. Mean duration of follow-up was 19 months for group 1 and 17 months for group 2. There were no statistically significant differences between the two groups in the rates of short-term success, long-term success, or major complications.

The total pooled major complication rate for both groups was 4.3%. Major complications occurred in three patients: 2/25 (8.0%) of the patients in group 1 and 1/44 (2.3%) of the patients in group 2. The major complications were as follows: two atrial perforations in group 1 (both requiring pericardiocentesis but no blood transfusion, one occurring during transseptal puncture and the other recognized in the

**Table 3.** Success and complication data

| | No. of patients | | |
|---|---|---|---|
| | Group 1 | Group 2 | *p* value |
| Short-term success (% of cases) | 24/25 (96) | 38/44 (86) | 0.20 |
| Long-term success (% of patients) | 21/23 (91) | 32/36 (89) | 0.76 |
| Major complications (%) | 2/25 (8.0) | 1/44 (2.3) | 0.39 |

postanesthesia recovery unit), and 1 patient with depressed function following RFA in group 2. This patient had complex cyanotic congenital health disease and had undergone a previous Blalock-Taussig shunt and bidirectional Glenn palliation. During the EP study, multiple etiologies of SVT were uncovered, including AVNRT, AVRT, and IART. The RF procedure was unsuccessful with six applications of RF energy applied (all within the atrium). The cardiac function was noted to be moderately depressed preprocedure and slowly worsened over the ensuing several months. No etiology for the decrease in function was determined, with no evidence for coronary compromise based on alterations in resting surface ECG or heart catheterization. It is not completely clear whether this decrease in function was due to the RFA procedure or represented the natural history of the patient's heart disease. Minor procedural complications were as follows: four patients in group 2 (3 AVRT, 1 AVNRT) had transient high-grade atrioventricular block that resolved prior to leaving the electrophysiology laboratory, and there were three hematomas in group 2 all of which were self-limited and none of which required transfusion. There were no procedure-related deaths in either group.

## Discussion

Radiofrequency ablation has been used for the treatment of SVT since 1989; soon thereafter, the first reports of RFA for SVT in children appeared [3, 6, 13, 14, 16, 17]. As the clinical experience and technology have improved, the indications for RFA have expanded to include younger and smaller patients. The largest body of experience concerning RFA in children has been gathered in the Pediatric Radiofrequency Ablation Registry [9, 10]. The most recent report of the full database in 1997 listed patient weight less than 15 kg as an independent risk factor for procedure-related complications. However, a subgroup analysis in 2001 of patients younger than 18 months old (all of whom weighed $< 15$ kg) showed no increased procedural risk relative to the rest of the database population [1].

The use of RFA for the management of SVT in infants and small children remains controversial. This controversy is highlighted by the recently published NASPE expert consensus conference in which the use of RFA in children younger than 5 years of age with SVT refractory to drag therapy, including sotalol and amiodarone, was believed to represent a class IIb indication [16]. Class IIb states that there is "clear disagreement of opinion regarding the benefit or medical necessity of catheter ablation."

SVT in infants usually either resolves spontaneously or can be managed using pharmacologic means. As reported by Weindling et al. [18] in 1996, only 7% of infants with SVT referred to a single tertiary care center required RFA for management of refractory tachycardia during the first year of life. Despite the more widespread use of more effective antiarrhythmic agents such as those in class Ic and class III, as well as combination therapy with both class Ic and III agents [8, 11], some infants remain refractory to medical management. Furthermore, pharmacologic management is not without complications, including systemic side effects as well as the risk of ventricular proarrhythmia.

In this report, patients $\leq 15$ kg (group 1) had a statistically greater incidence of structural heart disease than was found in children $> 15$ kg but $\leq 20$ kg (group 2). This difference is likely the result of several factors. By virtue of their small circulatory volume, smaller children tend to have less hemodynamic reserve than larger children. This lack of reserve can be compounded by the presence of significant structural heart disease. Thus, when an infant is confronted with both limited reserve due to size and heart disease, tachycardia is less well tolerated than in those patients not so encumbered. Such a clinical circumstance may require definitive therapy such as ablation, as occurred in at least one of our patients. Additionally, some children undergoing staged palliation of complex lesions develop limited access to certain chambers of their hearts following surgery and so undergo electrophysiological procedures in anticipation of upcoming surgery.

Despite the higher incidence of heart disease in group 1 patients, short- and long-term success rates were 96 and 91%, respectively, and did not differ significantly ($p > 0.05$) from those of group 2 patients (86 and 89%, respectively). In group 2, long-term success rates were slightly higher than short-term success rates because three Group 2 patients underwent

multiple RFA procedures during the study period, all of whom had at least one short-term failure followed by eventual short- and long-term success. These results are comparable to those previously reported for adults and children of all ages [9, 10].

The major concern regarding early ablation in small patients is the risk of complications. Most of the complications experienced by these patients were minor and resolved without intervention. Of the major complications, only two atrial perforations required percutaneous drainage. One perforation occurred during transseptal puncture and before the delivery of any radiofrequency energy. The procedure was terminated and the patient underwent immediate percutaneous drainage without any adverse hemodynamic effect. The second perforation was not appreciated until after the completion of the procedure and is thought to have occurred during RFA. The perforation was recognized when the patient developed tachycardia with distant heart sounds in the postanesthesia recovery area. The patient also underwent immediate percutaneous drainage with subsequent normalization of hemodynamics and clinical appearance. Because the preexcitation and SVT returned after discharge, the patient underwent successful ablation at a second session 6 months later without problems. Hence, the risk of atrial perforation may be higher among smaller patients undergoing catheterization, especially in the setting of transseptal puncture and RFA. There was no procedure-related mortality. One patient in group 2 with complex single ventricle anatomy died 6 months after a successful RFA due to complications related to the Fontan operation (plastic bronchitis).

Due to the large size of the catheters relative to these patients, the proximity of critical structures such as the atrioventricular node to arrhythmia substrates, and the possibility of lesion extension in immature myocardium, certain techniques are employed during EPS and RFA in these small patients to maximize procedural safety. These include the use of general anesthesia, use of an esophageal bipolar electrode lead that substitutes for a high right atrial catheter, use of a multipurpose catheter with electrodes located near the bundle of His and at the right ventricular apex [5], use of smaller (5 and 6 Fr) mapping and ablation catheters, fewer "test" or "insurance" applications of energy, RF application during ventilator apnea to improve catheter stability, lower maximal RF temperatures (usually limited to 50-55°C), and generally shorter RFA cycles of 30 seconds or less.

The major complication rates reported here are similar to those previously reported in infants from the pediatric RFA registry by Blaufox et al. [1]. However, that report excluded from the analysis 231 patients $>8$ months old and $<15$ kg. When these patients were combined with the $<18$ month group, the complication rate for all patients $<15$ kg exceeded that of patients $>15$ kg.

There are several limitations to this study. The first is that the distinction between infants and toddlers $<15$ kg and those 15-20 kg is somewhat arbitrary. These designations are usually defined by age rather than weight. Because physiologic age, as reflected in weight, rather than chronologic age may be important in assessing overall risk, we compared physiologic rather than chronologic groups. Our goal was to compare those patients who have been considered to be in the high-risk group (i.e., $\leq 15$ kg) with a group similar in size. Furthermore, because the necessity for performing RFA on the smallest patients is uncommon, the patient population size is limited. Due to the low incidence of complications, this study is not sufficiently powered to prove equivalency of these two groups. Therefore, although our results suggest that the procedural risks are similar for the two groups, they do not prove that RFA is as safe in the $\leq 15$-kg group as in the 15- to 20-kg group, and given the fairly low risk of complications in both groups, a significantly larger study would be required to do so. As mentioned, there may be a higher risk of atrial perforation in the $\leq 15$-kg group but more patients would be needed to evaluate this. Finally, because this series represents the experience from two centers with busy pediatric electrophysiology services, the results may not be applicable to all centers.

## Conclusion

These data suggest that the safety and efficacy of RFA for SVT in infants $\leq 15$ kg are similar to those for infants 15-20 kg, although the study is not powered to prove equivalency between the two groups. However, there may be a higher risk of atrial perforation in the $\leq 15$-kg group. Although caution continues to be warranted when considering RFA in small children, these data support the principle that the selective use of RFA is justified for the treatment of SVT in the smallest patients who have failed medical management and continue to have hemodynamically compromising SVT. Additionally, when considering RFA for the smallest patients, the experience of the center performing the procedure should be considered because our results were drawn from two high-volume centers with experience in ablation in infants.

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