Pediatr Cardiol 21:551–556, 2000
DOI: 10.1007/s002460010133

Pediatric
Cardiology

Radiofrequency Catheter Ablation: Indications and Complications

A.M. Dubin, G.F. Van Hare
Lucile Packard Children's Hospital at Stanford, 750 Welch Road, Suite 305, Palo Alto, CA 94304, USA

Abstract. Radiofrequency catheter ablation was first described in pediatric patients in the early 1990s. Since then, multiple advances in the technology and understanding of radiofrequency ablation have allowed this technique to blossom into one of the most powerful therapeutic tools available to the pediatric electrophysiologist. This treatment has, in the majority of cases, replaced arrhythmia surgery as the definitive cure for most arrhythmias. Ablation therapy is commonly implemented as an elective procedure to treat paroxysmal reentrant supraventricular tachycardia. There are several advantages to this therapy when used in the common indications: no exercise restrictions, no need for chronic drug therapy, and the avoidance of hospital visits for breakthrough episodes. This review will discuss the indications for radiofrequency ablation in the current era. In order to fully discuss this issue, this review will include the prior treatment of arrhythmias, current success rates, complications, and potential long-term issues.

Key words: Electrophysiology–Arrhythmia–Ablation–Pediatrics

Prior Therapy

Prior to 1989, arrhythmia management in children relied on one of three options. Many patients with hemodynamically stable paroxysmal attacks of supraventricular tachycardia (SVT) and a structurally normal heart have been (and continue to be) managed with no pharmacologic or interventional therapy. These patients and their parents may be taught the Valsalva maneuver or other maneuvers for termination of the tachycardia, and followed clinically. SVT is also often triggered by activity, and thus these patients may become significantly limited in their lifestyle. In this setting, antiarrhythmic therapy is commonly employed. However, any drug therapy carries the risk of significant side effects, especially proarrhythmia, and the need for daily dosing [3]. Prior to radiofrequency (RF) ablation, patients with severely refractory arrhythmias who were at high risk of sudden death underwent cardiac arrhythmia surgery [35]. The morbidity and occasional mortality associated with this therapy limited it to life-threatening arrhythmias or recurrent medically refractory tachycardia.

Natural History of SVT

Resolution

It is well established that patients who present with Wolff–Parkinson–White (WPW) or concealed accessory connections in infancy have a high probability of spontaneous resolution of their SVT during the first year of life. Studies in children with rapidly conducting accessory connections who present in infancy estimate the chance of resolution to be from 60% to 90% [3, 14]. Similarly, atrial ectopic tachycardias and persistent junctional reciprocating tachycardia have a 20% to 50% chance of improvement or resolution [11, 31, 33]. Patients older than the age of 5 have a very low chance of spontaneous resolution of their SVT [37]. However, of the patients who present in infancy with WPW and experience spontaneous resolution by 1 year of age, about one third will experience reonset of symptoms later in life, typically at approximately 4 to 6 years of life [37]. Patients with structural abnormalities and an arrhythmia, such as Ebstein's malformation of the tricuspid valve and WPW, also have a very low chance of spontaneous resolution [8, 37].

Thus, there is a strong possibility of spontaneous resolution of SVT in patients with accessory connections and a structurally normal heart if they present in the first year of life. However, if they continue to have or present with SVT after the age of 5, or have structural heart disease, the chance of SVT disappearing is very low. These facts need to be taken into consideration when contemplating RF ablation as a possible therapy.

Correspondence to: A.M. Dubin

Table 1. Success rates for specific tachycardia mechanisms [22, 23]

Diagnosis/accessory connection location	Initial success	Recurrence rates, 4 years post-RFA (%)
Right free wall accessory connection	928/1052 (88%)	25
Posteroseptal accessory connection	870/973 (89%)	21
Anteroseptal accessory connection	308/386 (79%)	15
Midseptal accessory connection	294/324 (91%)	
Left free wall accessory connection	2366/2486 (95%)	18
AVNRT	1701/1755 (97%)	19
Atrial ectopic tachycardia	347/397 (88%)	25
Atrial flutter	256/340 (75%)	67
Junctional ectopic tachycardia	16/19 (84%)	
Ventricular tachycardia	155/228 (68%)	26
All procedures	7241/7960 (91%)	

Cardiomyopathy

Patients with incessant tachyarrhythmias are at risk of developing congestive heart failure [12, 15, 16]. This is most commonly seen with various forms of incessant tachycardias, such as persistent junctional reciprocating tachycardia, atrial ectopic tachycardia, and junctional ectopic tachycardia, and it is thought to be secondary to both the high ventricular rates and the incessant nature of the arrhythmia [12, 15, 16, 44, 52]. These patients often present with an idiopathic dilated cardiomyopathy with what is initially thought to be a sinus tachycardia. With careful examination of the electrocardiograph, an arrhythmia is recognized. With treatment of their tachycardia, many of these cardiomyopathies will resolve [7, 24].

Sudden Death

In addition to cardiomyopathy, the other major risk of SVT is sudden death. This is an issue in children with WPW. In this situation there is a risk of atrial fibrillation with rapid conduction across the accessory pathway leading to ventricular fibrillation. This risk is thought to be low in the pediatric population because the risk of atrial fibrillation is thought to be low. However, sudden death in children with WPW has been reported [1]. The risk of sudden death associated with arrhythmia increases when there is associated structural heart disease [8, 37]. One cross-sectional pediatric study of WPW found a prevalence of sudden death similar to that of adult series (2.3%) [40].

Congenital Heart Disease

Several forms of congenital heart disease are associated with arrhythmias. As mentioned previously, these arrhythmias are less likely to spontaneously resolve [37]. They are also more likely to be symptomatic and be dangerous to these children because they are less able to handle the hemodynamic stress of rapid ventricular rhythms. There are also several palliative procedures (Mustard, Senning, and Fontan procedures) which are associated with atrial arrhythmias [13]. Patients with preexisting arrhythmia substrate are at high risk of arrhythmia in the immediate postoperative period, with potentially disastrous results when the child is in a fragile hemodynamic state.

Radiofrequency Ablation

Arrhythmia Substrate

For virtually every form of SVT, as well as VT, ablation has been attempted. Overall, the initial success rate for RF ablation is 91% for all arrhythmia substrates [21]. Table 1 shows data from the Pediatric Radiofrequency Catheter Ablation Registry regarding initial success rate by lesion and the 4-year recurrence rates. Most initial failures occur in right-sided accessory connections with a success rate of 88% to 90%.

Great success has been achieved with accessory connections, both manifest and concealed [2, 19, 29]. By mapping the location of the accessory connection (either by searching for the earliest ventricular activation during sinus rhythm in WPW patients or by mapping the earliest retrograde atrial activation in patients with concealed connections) RF energy can be delivered directly to the abnormal substrate. The treatment of permanent junctional reciprocating tachycardia, which uses a slowly conducting concealed connection, has been revolutionized with this therapy [44]. These children were previously at high risk of cardiomyopathy secondary to their arrhythmia and were very difficult to control with antiarrhythmic drug therapy. Radiofrequency ablation has

Table 2. Indications for pediatric radiofrequency ablation [48]

Class I indications	Class II indications	Class III indications
Incessant tachycardia, decreased EF, age < 4 years, unresponsive to amiodarone. Incessant tachycardia, decreased EF, age >4 years Paroxysmal symptomatic tachycardia unresponsive to all antiarrhythmics WPW, s/p cardiac arrest WPW, syncope, shortaccessory connection ERP, age >4 years	Incessant tachycardia, reduced EF, age <4 years Incessant tachycardia (other than JET), normal EF, age >4 years Incessant tachycardia, normal EF, age <4 years, responsive to amiodarone Paroxysmal symptomatic tachycardia, age >4 years Paroxysmal symptomatic tachycardia, age <4 years, unresponsive to medications (except amiodarone) WPW, symptomatic, age >4 years WPW, asymptomatic, age >4 years, with short RR in atrial fibrillation.	Incessant tachycardia, nl EF, age <4 years, responsive to medication (except amiodarone) Incessant JET normal EF, age <4 years responsive to medication (except amiodarone) Paroxysmal symptomatic tachycardia responsive to medications (except amiodarone), age <4 years Paroxysmal asymptomatic well-tolerated tachycardia WPW asymptomatic, long RR in atrial fibrillation WPW, symptomatic, age <4 years, long RR on medication

EF, ejection fraction; WPW, Wolff–Parkinson–White syndrome; JET, junctional ectopic tachycardia.

been found to be a very successful alternative in this scenario.

Atrioventricular node reentry tachycardia has also been successfully ablated in children. Although this disease process is relatively uncommon in infancy and early childhood, it is a common arrhythmia in adolescence [21]. Successful modification of the atrioventricular node with ablation of the slow pathway can be safely accomplished with a low incidence of heart block [9, 45]. Automatic focus tachycardias, such as atrial ectopic tachycardias, have been ablated with good success in children [53]. Atrial flutter is also treated with RF energy [46, 49]. This is most often a problem in children with congenital heart disease. By finding areas of slow conduction (surrounded by electrically inactive areas, such as incisional scars and anatomic barriers), one may successfully ablate these macrorentrant rhythms.

There has been limited success in attempting ablation of ventricular tachycardias in pediatric patients [34]. These rhythms may be very difficult to ablate because the patient may not tolerate sustained ventricular tachycardia for any period of time, and mapping may be difficult, especially in the setting of postoperative congenital heart disease such as tetralogy of Fallot.

Indications

Recommendation of RF catheter ablation is dependent on several factors, including age and clinical status of the patient as well as experience and success rates of the cardiologist or institution. We have previously reported a classification of indications for ablation which is based on a class I–III indication system, as used for pacemaker implantation guidelines and other procedures [48]. These will be briefly discussed here and are delineated in Table 2.

Class I indications for RF ablation, (i.e., there is substantial agreement that RF ablation is indicated) include those in which the patient is at risk of death. Patients with WPW syndrome who are s/p cardiac arrest as well as those who are known to have a malignant accessory connection and syncope are in this classification. Patients with incessant tachycardias who have signs of congestive heart failure are also at risk of death and should undergo RF ablation.

Class II indications (ablation is frequently performed but there is a divergence of opinion with respect to the necessity of the procedure) include patients with paroxysmal tachycardia older than the age of 4 and those who are unresponsive to drugs other than amiodarone and are younger than 4. Patients with WPW syndrome who are asymptomatic but have a rapidly conducting accessory connection are also classified in this category.

Class III indications are conditions for which there is general agreement that RF ablation is not indicated. These mostly deal with children who are less than age 4 and who either can be well controlled on medication or are asymptomatic.

Complications/Risks

The risks of RF ablation in children are similar to those in adults. The Pediatric Electrophysiology Society has reported a major complication rate of 2.9% based on the Radiofrequency Ablation Registry data [23]. Risks of the procedure include bleeding, stroke, infection, damage to cardiac valves, cardiac perforation, atrioventricular block, and coronary spasm. The most significant of these will be discussed in detail.

Mortality

Schaffer et al. [42] presented mortality data from the Pediatric Radiofrequency Ablation Registry data. They found 10 deaths in 4651 procedures (0.2%) which could potentially be related to RF ablation. Death was related to traumatic injury in 2 patients, it occurred due to thromboembolism in 2 patients, and was of unknown etiology in the remaining 6 patients. Two patients most likely died as a result of an arrhythmia that may have been related to the ablation procedure. Mortality was more frequent with underlying heart disease and was not related to operator experience. There was also an association between mortality and lower patient weight and a greater number of RF lesions in patients with structurally normal hearts.

Atrioventricular Block

Schaffer et al. [43] published the RF ablation registry data regarding heart block in 1996. They found that atrioventricular block occurred in 23 of 1964 ablations (1.2%). These consisted of 14 complete heart block cases (3 transient) and 9 second-degree block cases (5 transient). The risk of developing heart block was related to the site of ablation: 2% of anteroseptal connections, 10% of midseptal connections, 1% of right posteroseptal connections, and 1.6% of atrioventricular nodal reentrant tachycardia ablations. Experience of the cardiologist was found to be the only significant risk factor. The risk of atriovetricular block in this study was lower than the risk reported in several adult studies [17, 19, 54]. However, the risk of recurrence of arrhythmia after an initially successful ablation procedure in the septal area was higher than in other adult studies (20 vs 6–12%) [5, 6, 27]. This may suggest that the pediatric electrophysiologist has a less aggressive approach in the septal region.

Transseptal vs Retrograde Approach

There have been several conflicting reports regarding the appearance of valvar insufficiency following retrograde approach in left-sided pathways. Minich et al. [32] showed a 30% increase in aortic insufficiency and 12% increase in mitral insufficiency following ablation. However, the degree of insufficiency was mild in all patients. Other centers have not reported as high an incidence of these complications when using a retrograde approach [25, 51]. Many pediatric centers have advocated a transseptal approach to left-sided ablations. However, the transseptal approach is not without risks. There have been reports of air emboli and perforation with this approach [28, 30]. It appears that operators who are experienced in both techniques are able to achieve success with low complication rates [18].

Embolic Complications

The overall incidence of thromboembolic complications has been reported to be between 0.6% and 1.3% [17, 18, 25, 55]. The risk is increased in left heart ablations (1.8–2%) and ventricular tachycardia ablations (2.8%) [55]. No relationship has been identified between the anticoagulation regimen used during or after the procedure and the incidence of embolism.

Radiation Exposure

Rosenthal et al. [39] published a multicenter trial regarding fluoroscopy and radiation exposure. They examined radiation exposure in 860 patients, of which 234 were under the age of 17 years [39]. They found radiation exposure to be significantly reduced with younger age. Patients less than 10 years old required a median of 28 minutes fluoroscopy time, those between the ages of 10 and 17 required 35 minutes, and those older than 18 years required 45 minutes. Radiation exposure was also significantly decreased in children, with 89% of children receiving $<2\ S_v$ (the threshold dose for the earliest sign of radiation skin injury). New technologies, such as intravascular ultrasound and three-dimensional nonfluoroscopic mapping systems, and improved operator experience should decrease the risk of radiation exposure even further.

Animal Studies

Several studies have examined the effect of RF energy on immature myocardium. Saul et al. [41] reported the results of RF lesions in infant lambs. They found that the lesions created in the lambs were much deeper than those in adult animals. They also reported that the lesions increased in size with animal growth. The authors then postulated that these results must be taken into account when contemplating ablation therapy in very young children. They recommended avoiding intervention in the youngest patients until technical improvements allow for real-time assessment of lesion size during ablation.

Coronary Artery Involvement

Paul et al. [36] published a study that examined RF ablation in young pigs. They found that ablating in the right atrial aspect of the tricuspid valve annulus resulted in extension to the right coronary artery layer in four of five animals. More disturbing was the fact that the lumen of the right coronary artery was narrowed between 25% and 40% in two animals secondary to intimal thickening. Several case reports in both adults and children have found acute coronary artery occlusion following both left-sided and right posteroseptal accessory connection ablation [4, 20, 38]. Additional studies in long-term follow-up in humans need to be undertaken in light of these disturbing findings.

Follow-Up

Currently, follow-up data are restricted to data available from the ablation registry (with the inherent difficulties of a voluntary registry) and a small number of single center studies. Van Hare [47] found a recurrence rate of 11% of patients ablated for supraventricular tachycardia, with a mean follow-up interval of 16 months. The recurrences occurred mainly in patients with right-sided connections and AVNRT. These data are echoed in the ablation registry with an overall recurrence rate of 23%, again mostly in lesions with a high likelihood of atrioventricular nodal block [26]. A multicenter prospective trial is under way to determine long-term results from RF ablation in pediatric patients.

Conclusions

The use of RF ablation as a potential cure for multiple arrhythmias has increased greatly during the past 9 years. With a high initial success rate of 92%, it is a very attractive alternative to a lifetime of medications and a necessary option when faced with life-threatening arrhythmia or medically refractory arrhythmia-induced cardiomyopathy. However, it is important when considering this therapy to also take into account the known risks associated with the procedure as well as some of the unknown long-term issues. The clinician will need to carefully assess each patient's history, risk factors, and response to medications to determine when to ablate and when to wait.

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