Original Research

Cryoablation Versus Radiofrequency Ablation for Atrioventricular Nodal Reentrant Tachycardia in Children: Long-Term Results

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Key words:
Radiofrequency ablation, cryoablation, atrioventricular nodal reentrant tachycardia, children, pediatric

Introduction: Cryoablation is used increasingly for the treatment of atrioventricular nodal reentrant tachycardia (AVNRT). We sought to compare the long-term outcomes of cryoablation (Cryo) vs. radiofrequency (RF) ablation for the treatment of AVNRT in children.

Methods: Two groups of consecutive patients were analyzed retrospectively: the RF group, 20 patients (60% males, mean age 13.25 ± 2.59 years), and the Cryo group, 20 patients (55% males, mean age 12.17 ± 3.07 years). Follow up was 52.7 ± 16.5 months for the RF and 32.8 ± 11.9 months for the Cryo group.

Results: Acute success rates (100% for RF vs. 90% for Cryo), procedural times (147.75 ± 37.15 min for RF vs. 184.4 ± 75.59 min for Cryo), and fluoroscopy times (10.9 ± 6.46 min for RF vs. 6.41 ± 6.92 min for Cryo) were not statistically significantly different between the two groups. The number of lesions was significantly higher in RF than in Cryo (8.85 ± 6.63 vs. 3.6 ± 1.9, p=0.007). Transient AV block during ablation occurred in 1 patient in each group. No permanent AV block was observed. Recurrence rate was 10% in the RF and 27.7% in the Cryo group (p=0.222) occurring up to 14 months after the procedure.

Conclusion: Cryoablation is safe and effective for the treatment of AVNRT in pediatric patients, but there is a tendency for higher recurrence rates compared to radiofrequency ablation. Techniques to reduce recurrence rates after cryoablation are needed.

Manuscript received:
February 23, 2009;
Accepted:
May 19, 2009.

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Atrioventricular nodal reentrant tachycardia (AVNRT) is the second most common form of paroxysmal recurrent tachycardia in children.[1] It may cause significant symptoms, ranging from palpitations to chest pain and syncope, and may lead to significant patient and parental anxiety, loss of schooldays and exclusion from sports. Radiofrequency ablation has become the first-line therapy for AVNRT, with high success and low recurrence rates.[2,3] However, a small but definite risk of damage to the atrioventricular (AV) node still exists.[2] In younger children the risk may be higher because of geometric limitations and many operators avoid ablation or postpone it for a few years. In the last few years cryoablation has emerged as a safer method of ablation for AVNRT because of its unique characteristics. These are: 1) slower lesion formation and reversible effects during initial phases of application, allowing for "cryomapping" with virtually no risk of AV block; and 2) firm attachment of the catheter to tissues during freezing, i.e. "cryoadhesion".[4] The disadvantages of cryoablation may be a lower efficacy and a higher recurrence rate. Few studies have compared the two techniques in children and there are no studies

with long-term follow up. We have therefore reviewed our results from AVNRT ablation with the two techniques, including only patients with a follow up longer than 12 months.

Methods

Patients

AVNRT was diagnosed according to standard criteria.[5] Two groups of patients were analyzed retrospectively. The RF (radiofrequency ablation) group consisted of 20 children (12 females), 7-18 (13.25 ± 2.59) years old, who underwent radiofrequency ablation from 06/2002 to 10/2005. The Cryo (cryoablation) group consisted of 20 pts (11 females), 8.5-18.0 (12.17 ± 3.07) years old, who underwent cryoablation from 2/2005 to 11/2006. Three patients in the Cryo group had an additional arrhythmogenic substrate: an ectopic atrial focus in the left upper pulmonary vein, a nodoventricular fiber, and a left-sided accessory pathway. No patient in the RF group had other arrhythmogenic substrates (Table 1).

The study complied with the Declaration of Helsinki and the research protocol was approved by the Hospital ethics committee. Informed consent was obtained from the parents of all patients.

Electrophysiology study

All patients underwent a diagnostic electrophysiologic study under general anesthesia, except for two patients in the cryoablation group who received conscious sedation. Diagnostic quadripolar catheters were placed through the femoral veins to the high right atrium, His bundle, coronary sinus, and right ventricular apex. If tachycardia was not inducible, isoproterenol infusion was started and the rate titrated to patient response (heart rate increase by 25-30% from baseline). If tachycardia was still non-inducible, double and triple atrial extrastimuli were used and atropine (0.04 mg/kg as a bolus) was given if necessary.

Table 1. Demographic and arrhythmia data.

	RF group	Cryo group
Age (yrs)	7-18 (13.25 ± 2.59)	8.5-18 (12.17 ± 3.07)
Males/Females	8/12	9/11
Typical AVNRT	20	20
Atypical AVNRT	2	2
Additional arrhythmia	0	3

AVNRT – atrioventricular nodal reentrant tachycardia; Cryo – cryoablation; RF – radiofrequency ablation.

Ablation techniques

RF group

Slow pathway ablation was accomplished by a combined anatomic and electrogram recording approach from the right side in all patients. The part of the tricuspid annulus between the lower end of the coronary sinus orifice and the location of the His bundle was divided into 3 areas (P, M and A) and each area was subdivided in 2 (P1, P2, M1, M2 and A1, A2) according to Jazayeri et al.[6] The tip of the mapping catheter was positioned at the triangle of Koch, at P1-M2 locations with a small atrial and large ventricular signal (A:V ratio of 1:2 or less), and radiofrequency energy was delivered with temperature control (T max 50-60^{o} C). A stable junctional rhythm with 1:1 VA conduction was used as an indicator of an effective and safe application. The endpoint of the procedure was non-inducibility of AVNRT despite all the above measures. If dual AV nodal physiology (AH jump and/or sustained slow pathway conduction) with up to one AV nodal echo beat persisted without AVNRT inducibility, this was acceptable and further attempts were not made.

Cryo group

A 6 mm cryoablation catheter was used in all studies. The tip of the catheter was positioned in the same manner as in the RF group but at somewhat more cephalad locations (P2-A1). Cryomapping (T min -30^{o} C) was performed initially. If there was no evidence of AV conduction impairment during cryomapping (including even mild prolongation of the AV interval), freezing at -70^{o} to -80^{o} for 4-6 min was performed immediately (cryoablation). The endpoint of the procedure was non-inducibility of AVNRT and, when possible, elimination of slow pathway conduction (elimination of AH jump and sustained slow pathway conduction during decremental pacing). To achieve this, it was sometimes necessary to move the catheter closer to the compact AV node than with radiofrequency ablation. During cryoablation, we routinely performed decremental atrial pacing. It was common to see prolongation of the Wenckebach cycle length during freezing, sometimes by as much as 20%, despite a stable PR interval at baseline. We initially stopped freezing if this was observed, but we realized that as long as prolongation was not marked (i.e. no more than 20% from baseline) and no PR prolongation was seen during sinus rhythm while freezing, this was always a reversible effect.

Post-ablation evaluation

After a successful ablation, a waiting period of 30 minutes was allowed, and a repeat electrophysiologic study was performed, both at baseline and during isoproterenol infusion. If the endpoints were achieved, the procedure was terminated and the catheters were removed. Patients were watched in-house for 24 hours, with continuous ECG monitoring. Twelve-lead ECG and 24-hour Holter monitoring were performed. Two-dimensional echocardiography was used only if an excessive number of applications had been required or if there were other procedural indications. Aspirin was given only in RF group patients and in some Cryo group patients with a large number of applications. Routine follow up was done at 2, 6 and 12 months post ablation in the outpatient clinic, and as necessary thereafter.

Statistical analysis

The Kolmogorov-Smirnov test was used to assess whether continuous data followed a normal distribution. The t-test was used if variables followed a normal distribution and the Mann-Whitney U-test when the distribution was not normal. The chi-square test was used for categorical variables. The analysis was performed using SPSS 11.0 for Windows.

Results

Procedural data

Procedural variables and the outcomes of the two groups are given in Table 2. The procedure duration and fluoroscopy times were not significantly different in the two groups. The number of cryo-applications was significantly less than the number of radiofrequency applications (p=0.007). There was no statistically significant difference in any other parameter. No AV conduction abnormalities were identified on a 24h Holter recording after the procedure.

RF group

All patients in the RF group had typical AVNRT (cycle length, CL 303.8 ± 55.15 ms). Two patients also had atypical forms of AVNRT (one slow-slow, one fast-slow). All patients had an initially successful procedure. The more cephalad sites of RF application that were required ranged from P1-M2 (2 P1, 2 P2, 10 M1 and 6 M2). An accelerated junctional rhythm was observed in all patients at the successful ablation site. The number of radiofrequency applications ranged from 1 to 26 (8.85 ± 6.63). The power used ranged from 14-50 W and the maximum temperature achieved was 47-60^{o} C (55 ± 4). Fluoroscopy time ranged from 2.3-27 (10.9 ± 6.46) min and procedure duration was between 90-210 (147.75 ± 37.15) min. There was transient 2:1 AV block in 1 patient with typical AVNRT, lasting for 15 min. No other complications occurred.

Cryo group

All patients in the Cryo group had typical AVNRT (CL 301.25 ± 61.76 ms). Two patients also had atypical forms (one slow-slow, one fast-slow). The cryoablation procedure was successful in 18 patients (90%). One patient required application of radiofrequency lesions in the left posteroseptal area (delivered via a transseptal approach) for final success. The other non-successful procedure was terminated because

Table 2. Procedural characteristics.

	RF Group	Cryo Group	p value
Number of lesions:			
Range	1-26	1-10	0.007
Mean ± SD	(8.85 ± 6.63)	(3.95 ± 2.39)	
Procedure duration:			
Range	90-120	120-480	NS
Mean ± SD	(147.75 ± 37.15)	(184.4 ± 75.59)	
Fluoroscopy time:			
Range	2.3-27	0.5-31.2	NS
Mean ± SD	(10.9 ± 6.46)	(6.41 ± 6.92)	
Acute success	20/20 (100%)	18/20 (90%)	NS
Complications (transient AV block)	1	1	NS
Recurrence	2/20 (10%)	5/18 (27.7%)	NS

AV – atrioventricular; Cryo – cryoablation; RF – radiofrequency ablation.

of Wenckebach type AV block during cryoablation. The more cephalad sites of cryoablation that were required were between P2-A1 (1 P2, 13 M1, 5 M2 and 1 A1). The number of cryolesions ranged from 1-10 (3.95 ± 2.39) and the lesion duration was between 4-6 min. The number of lesions was 3.5 ± 2.0 in successful procedures and 7.5 ± 3.5 in unsuccessful procedures. The number of lesions in patients who had a recurrence was 4.2 ± 2.6 and in those without recurrence it was 3.3 ± 1.8 (p=0.101). The lowest temperature recorded was -70 to -85°C. Fluoroscopy time ranged from 0.5-31.2 (6.4 ± 6.92) min and procedure duration from 120-480 (184.4 ± 75.59) min. There was transient second degree AV block during cryomapping in one patient, which resolved within a few minutes.

Follow up

Follow up was via telephone or clinic visit and was complete for all patients. RF group patients were followed for 33-84 (mean 52.7 ± 16.5) months and Cryo group patients for 21-64 (mean 32.8 ± 11.9) months. There were 2 recurrences in the RF group (10%) at 1 week and 9 months after the initial procedure. Both of these patients underwent successful repeat radiofrequency ablation with no further recurrence. There were 5 recurrences after 18 acutely successful procedures in Cryo group (27.7%) at 0.1 to 14 months of follow up (p=0.222). The average time to recurrence was 4.02 ± 5.77 months. Three of these patients underwent successful repeat cryoablation, with no recurrence in 2 of them at follow up of 16 and 18 months. In the other two patients conservative follow up was preferred, since the episodes were very infrequent compared to the pre-ablation period.

Discussion

This is the first study to compare the long-term results of cryoablation and radiofrequency ablation for the treatment of AVNRT in pediatric patients. The few previously published studies comparing radiofrequency to cryo-energy in both pediatric and adult patents have had relatively short follow-up periods, ranging from 0.8 to 30 months. However, the average follow-up period in all studies was less than 13 months.[4,7-13] Our average follow-up time was significantly longer, at 32.8 ± 11.9 months, with all patients having more than 12 months' follow up. The average time to recurrence in our patients was 4.78 ± 6.37 months, with the latest recurrence occurring 14 months after cryoablation.

In our population, the acute success rate of cryoablation was not statistically different from that of RF ablation, especially if one considers that in the single case where crossover to RF ablation was required the location of the successful ablation site was in the left posteroseptal area, an unusual but well known observation.[14] It is possible that the same effect could have been achieved with cryoablation if attempts had been made on the left side with this modality.

Few studies have been published on the treatment of pediatric patients with AVNRT using cryoablation.[7-12] These reports of cryoablation for treatment of AVNRT had acute success rates of 83% to 96%, similar to our results. Papez et al[7] had higher success rates relative to previous reports (96%). Factors that potentially contributed to their higher success were: a) delivery of several additional lesions adjacent to the successful ablation site; b) initial targeting of the slow pathway at a more anterior site closer to the AV node; and c) the use of a 6 mm tip catheter, which generates larger lesions. As our experience with the procedure has evolved, we have also made it a common practice to start applications in the mid-septal area, slightly above the coronary sinus ostium and proceed cephalad if initial lesions are not successful. We too, have started applying "insurance" lesions close to the successful site. In addition, we perform decremental pacing during cryoablation to assess for prolongation of the Wenckebach cycle length. We accept prolongation up to 20% from baseline, which is always reversible, and we have attributed it to the formation of the ice-ball. In fact this may be a sign of a favorable cryoablation location, analogous to the accelerated junctional rhythm seen during radiofrequency ablation.

Complication and recurrence rates

Transient AV block occurred in 1 patient in each group during ablation and no permanent AV block was observed in either group. The low incidence of complications and the small number of patients does not allow meaningful statistical comparison. The use of cryomapping is an additional "safety net", although some authors have reported that the effect of cryomapping is not always predictive of the effect of cryoablation.[11] However, even AV block occurring during cryoablation is reversible during the early phase of application. This fact has made cryoablation the preferred modality in many pediatric electrophysiology laboratories.

The recurrence rate in our Cryo group was higher than previously reported in adult and pediatric series. However, Gupta et al reported a recurrence rate of 19.7% at a mean follow-up time of only 57 days,[13] Papez et al reported recurrence in 12% of patients over a mean follow-up period of 8.1 months,[7] and Collins et al reported a recurrence rate of 8% over a median follow-up period of 1 year.[8] Since one of the recurrences in our patient population occurred 14 months after ablation, we believe that the lower recurrence rate of other studies may be in part due to the markedly shorter follow-up periods.

Limitations of the study

The main limitations of this study are its retrospective nature and the small number of patients. The groups are comparable in terms of age and types of AVNRT. Even though our Cryo group had additional arrhythmia substrates in 3 patients, these did not affect the final outcome (all recurrences were due to AVNRT and not to the other arrhythmia types). There was also no uniform approach regarding the delivery of additional safety lesions after an initially successful cryoablation lesion.

Clinical implications

Although the arrhythmia recurrence rate is higher than that of RF ablation, cryoablation offers several advantages, such as greater safety regarding the AV conduction system and the coronary arterial circulation,[15] which are of paramount importance in young patients with smaller and growing hearts. During preprocedure discussion and informed consent, most of the parents of our patients prefer the higher risk of recurrence to the small but existent risk of AV block and damage to the coronary arteries. It is our task to improve the acute and long-term results of cryoablation as more experience is accumulated in pediatric and adult electrophysiology laboratories. We suggest that future studies should evaluate prospectively the use of indicators of effective cryoablation, such as: 1) transient prolongation of the Wenckebach cycle length during cryoablation; 2) elimination of dual AV nodal physiology; and 3) application of additional cryolesions after an "effective lesion". In addition, longer follow up should be considered to detect late recurrences.

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