Transcatheter Cryoablation of Tachyarrhythmias in Children
Initial Experience From an International Registry

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OBJECTIVES
We sought to describe the early pediatric experience of transcatheter cryoablation, and identify whether specific arrhythmia substrates and/or ablation locations were particularly suited to cryoablation.

BACKGROUND
Radiofrequency (RF) ablation has become established therapy for pediatric tachyarrhythmias. However, challenges remain in terms of the safety and efficacy of RF ablation in specific locations; new methods may address these issues.

METHODS
Prospective data were available for 64 patients age 13 ± 4 (mean ± SD) years undergoing cryoablation at 14 centers participating in the Cryocath International Patient Registry. Dysrhythmia duration was 5.0 ± 4.2 years, with diagnoses of atrioventricular node re-entrant tachycardia (AVNRT) (n = 30), anteroseptal (n = 11), midseptal (n = 5), or other (n = 15) accessory pathway (AP) mediated AV re-entry, ventricular tachycardia (VT) (n = 3), and ectopic atrial tachycardia (EAT) (n = 2). Two patients had more than one arrhythmia substrate. Transcatheter cryoablation was offered by cardiologist preference after written informed procedural consent of each patient and/or legal guardian. Cryomapping was performed at −30°C and cryoablation was delivered with 4-min applications at −75°C.

RESULTS
Acute success was achieved in 45 of 65 (69%) cryoablation patients, with best success rates in AVNRT (83%) and right septal AP (75%), and lower success rates in other AP (43%), VT (66%), and EAT (0%). No device-related adverse events were reported. The success of radiofrequency (RF) ablation applied in 14 cryoablation failures was 4 of 4 for AVNRT patients, 1 of 1 for anteroseptal AP patients, 5 of 6 for other AP patients, 0 of 1 for VT patients, and 0 of 2 for EAT patients.

CONCLUSIONS
Transcatheter cryoablation is a safe and well-tolerated alternative to RF ablation in pediatric patients on the basis of our initial experience. Success is highest in AVNRT and in substrates recognized as technically challenging or risky for RF ablation. (J Am Coll Cardiol 2005;45: 133–6) © 2005 by the American College of Cardiology Foundation

Radiofrequency (RF) ablation has become established therapy for pediatric tachyarrhythmias (1,2). However, challenges remain in terms of the safety and efficacy of RF ablation in specific locations, including the potential for injury to the coronary arteries, particularly when ablating within the coronary sinus and coronary veins (3–14). There continues to be a significant risk of ablation-induced atrioventricular (AV) block (15), particularly in right septal locations (16). The right AV groove may be a difficult location to achieve adequate catheter contact and stability, resulting in disappointing ablation results (17). Recently, transcatheter cryoablation delivery systems appropriate for pediatric use have been developed (18–23).

We sought to evaluate the safety and efficacy of early pediatric experience of transcatheter cryoablation as recorded in a prospective multicenter cryoablation procedure registry, as well as attempting to identify whether specific arrhythmia substrates and/or ablation locations were particularly suited to this new method.

METHODS
Prospective data collection was performed for all patients <18 years of age undergoing a transcatheter cryoablation procedure using a Cryocath (Kirkland, Canada) system. There were 14 centers in 8 countries, all participating in the Cryocath International Patient Registry. Cryoablation was offered by physician preference, in most cases based on substrate location, with informed consent after local regulatory approval. Outcome measures were determined as for RF ablation.

After standard electrophysiologic assessment, a 7-F cryoablation catheter (Freezor 4 mm tip or Freezor Xtra 6 mm tip, CryoCath) was introduced via femoral (62 patients) and/or other (5 patients) venous and/or femoral arterial (1 patient) access. Cryomapping at −30°C for up to 60 s was performed and the arrhythmic substrate re-evaluated. Catheter adherence to the endocardium during the cryomap allowed for extrastimulus testing for inducibility, or in the case of atrioventricular nodal re-entrant tachycardia (AVNRT), assessment of slow
pathway function. Cryoablation was performed at $-75^\circ$C for a 4-min period.

RESULTS

There were 66 cryoablation attempts in 64 patients (36 males) age 1 to 18 years (mean $\pm$ SD, 13 $\pm$ 4 years). Two patients had dual substrates. One patient had congenital heart disease, with a previous repair of tetralogy of Fallot.

The distribution of arrhythmia substrates, as well as the procedural times and fluoroscopy times, stratified by substrate, are shown in Table 1. Procedural data were unavailable for one of the ectopic atrial tachycardia (EAT) cases. Thirty of the 66 cryoablations were for AVNRT. There were 30 cryoablations of accessory pathways (APs), one-half of which were right anteroseptal or midseptal.

The number of cryomaps and cryoablations, stratified by success and failure, is reported in Table 2. Although there appears to be a trend toward higher mean numbers of maps and ablations in failed attempts, the distributions are skewed and the medians are not dissimilar ($p = NS$ by rank-sum test).

Best success rates (Table 1) were seen in AVNRT (83%) and right septal accessory pathways (75%), with lower success rates in other APs (43%) and ventricular tachycardia (VT) (66%). There were no reported successes in cryoablation of EAT, although the denominator is only two.

We evaluated the fate of failed cryoablation attempts (Table 1). Of the five failures of cryoablation in AVNRT, four were successfully treated by RF ablation. Of the four failed cryoablations of anteroseptal and midseptal APs, three were abandoned at the discretion of the clinician, and one anteroseptal AP was successfully RF ablated. Of the eight failed cryoablations for other APs, three were in the right posterior septum, two in the left posterior septum, one within the coronary sinus, and two on the left free wall. Two of these cases were abandoned, and five of the six remaining APs were successfully ablated with RF. All of the failed VT or EAT cryoablations also failed RF ablation.

From the patient’s point of view in this series, the procedural success rate for ablation of AVNRT or AP, from any energy source, was 97% for AVNRT and 80% to 86% for APs, most of which were in right septal locations.

Adverse events. There were no complications of electrophysiologic (EP) study or cryoablation, specifically no cardiovascular injury and no permanent AV block. During cryomapping, transient observations of AV conduction abnormalities ranging from first degree AV delay to complete heart block were anecdotal observed, particularly in right septal locations; all of these were immediately reversed upon rewarming. One adverse event of “prolonged hospitalization due to prostatitis” was of uncertain relationship to the initial procedure. By way of comparison, a 3% to 4% overall complication rate for EP study and RF ablation has been shown in the Prospective Assessment after Pediatric Cardiac Ablation (PAPCA) study and its associated registry (17), whereas the reported incidence of AV block caused by RF ablation is 1.2% for AVNRT and 3.6% for all right septal pathways (24). In a review of a single center’s experience of 145 septal APs, four cases of permanent AV block in 47 attempted anteroseptal and midseptal ablations were observed, for a site-specific AV block rate of 8.5% (16).

Follow-up. Three-month follow-up data were available for 28 of the 45 acutely successful cryoablations. There were four reported recurrences: two of AV node re-entry, one posteroseptal AP, and one VT. Depending on which denominator one uses, this may suggest somewhere between 9% and 14% recurrence rates. Because the follow-up data are incomplete, a selection bias to follow-up in the recurrence patients would be a reasonable assumption, and thus the recurrence rate may not be dissimilar from the PAPCA experience of 7% and 9% at two and six months, respectively (25).

DISCUSSION

Efficacy and safety. This report represents the initial pediatric experience (as recorded in an international registry)

<table>
<thead>
<tr>
<th>Substrate</th>
<th>N</th>
<th>Procedure Mean $\pm$ SD (min)</th>
<th>Fluoroscopy Mean $\pm$ SD (min)</th>
<th>Cryo Success N (%)</th>
<th>Cryo Failure N (%)</th>
<th>RF Success N of N Attempts</th>
<th>Combined Success, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVNRT</td>
<td>30</td>
<td>168 $\pm$ 51</td>
<td>17 $\pm$ 10</td>
<td>25 (83%)</td>
<td>5 (17%)</td>
<td>4 of 4</td>
<td>97%</td>
</tr>
<tr>
<td>Anteroseptal AP</td>
<td>11</td>
<td>184 $\pm$ 64</td>
<td>40 $\pm$ 34</td>
<td>8 (73%)</td>
<td>3 (27%)</td>
<td>1 of 1</td>
<td>82%</td>
</tr>
<tr>
<td>Midseptal AP</td>
<td>5</td>
<td>215 $\pm$ 70</td>
<td>46 $\pm$ 47</td>
<td>4 (80%)</td>
<td>1 (20%)</td>
<td>0 of 0</td>
<td>80%</td>
</tr>
<tr>
<td>Other AP</td>
<td>14</td>
<td>230 $\pm$ 94</td>
<td>35 $\pm$ 19</td>
<td>6 (43%)</td>
<td>8 (57%)</td>
<td>5 of 6</td>
<td>86%</td>
</tr>
<tr>
<td>VT</td>
<td>3</td>
<td>195 $\pm$ 96</td>
<td>21 $\pm$ 12</td>
<td>2 (67%)</td>
<td>1 (33%)</td>
<td>0 of 1</td>
<td>67%</td>
</tr>
<tr>
<td>EAT</td>
<td>2*</td>
<td>75 $\pm$ 0*</td>
<td>5 $\pm$ 0*</td>
<td>0 (0%)</td>
<td>2 (100%)</td>
<td>0 of 2</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Data not available for 1 EAT ablation case. In several cases of failed cryoablation, radiofrequency ablation was not attempted.

AP = accessory pathway; AVNRT = atrioventricular nodal re-entrant tachycardia; EAT = ectopic atrial tachycardia; RF = radio frequency; VT = ventricular tachycardia.
of the use of a novel transcatheter cryoablation system. Acute success rates of 83% and 75% for AVNRT and right septal APs are similar to those of the early era of the pediatric RF ablation experience (1,26). Most impressively, there were no reports of injury to the normal conduction system, a finding similar to the larger adult experience with this form of ablation energy (27,28). Although the follow-up data in the Cryoablation Registry are incomplete, the recurrence rates are not dissimilar to those seen after RF ablations.

**Acute failure of cryoablation.** Although there were less impressive acute success rates in posteroseptal and free wall locations, most of these pathways were subsequently successfully ablated using RF energy, suggesting that lesion size and delivery may have played a role in these locations (29,30). In contrast, the failure of RF ablation following attempted cryoablation of VT and EAT suggests that the ablation energy source and mode of delivery were not responsible in these cases.

**Unique features of cryoablation.** The reversibility of cryomapping provides the opportunity for forgivable test lesions in locations known to be at high risk for heart block during empiric RF ablation. Accompanying this is the ability to formally test AV nodal physiology as well as arrhythmia inducibility during both cryomapping and cryoablation (28). The intrinsic catheter stability related to cryoadhesion prevents dislodgement during ablation. All of these characteristics are expected to enhance both safety and efficacy (27,31,32).

**Issues remaining to be resolved.** The disappointing performance during this early cryoablation experience in the ablation of some APs is most likely related to the smaller lesion size with initial versions of the cryoablation catheter, leading to a smaller effective target area being ablated. The issue of convective heat loss during cryoablation on the atrial side of the left AV groove has been suggested as playing a role (30), with some centers reporting better success when using a retrograde approach in adults, although the safety and efficacy of a retrograde approach with the relatively stiff cryoablation catheter has not been evaluated in children (Dr. M. Dubuc, personal communication, March 2003). Newer cryoablation catheters with larger tip surface areas and/or modified coolant gas parameters may offer a benefit in these situations.

Similar to the early experience with RF ablation (26), it is reasonable to expect that a learning curve exists for the attainment of proficiency in utilizing cryoablation. Acute success rates as well as recurrence risks are currently acceptable, but should eventually approach those of established modalities. The established safety of cryoablation in high-risk locations should allow the effective ablation of arrhythmias that otherwise might be abandoned, or perhaps ablated with a requirement for permanent pacing (16).

**Conclusions.** Cryoablation is a safe and effective alternative to RF ablation and appears to offer unique advantages related to catheter stability during energy delivery, as well as the safety of reversible mapping lesions in high-risk locations.

Acknowledgment

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### Table 2. Cryoablation Details

<table>
<thead>
<tr>
<th></th>
<th># of Cryomaps</th>
<th># of Cryoablations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Median [Range]</td>
</tr>
<tr>
<td>Success</td>
<td>5.6 ± 3.2</td>
<td>2.9 ± 3.3</td>
</tr>
<tr>
<td></td>
<td>6 [0–12]</td>
<td>2 [0–17]</td>
</tr>
<tr>
<td>Failure</td>
<td>9.1 ± 6.8</td>
<td>6.4 ± 6.7</td>
</tr>
<tr>
<td></td>
<td>6 [2–22]</td>
<td>3 [0–20]</td>
</tr>
</tbody>
</table>

All p = NS by rank-sum test for # of cryomaps or cryoablations, success versus failure.

### References


APPENDIX

Centers submitting pediatric cases to the Cryocath International Patient Registry: Allgemeines Krankenhaus St. Georg, Hamburg, Germany; Deutsches Herzzentrum, Munich, Germany; Elektrophysiologie Bremen, Bremen, Germany; Erasmus Medical Centre, Rotterdam, the Netherlands; Hospital Europeen Georges Pompidou, Paris, France; Hospital for Sick Children, Toronto, Canada; Illinois Masonic Medical Center, Chicago, Illinois; Institut de Cardiologie de Montreal, Montreal, Canada; Karolinska Hospital, Stockholm, Sweden; Kerchoff-Klinik, Bad Nauheim, Germany; Mauriziano Hospital, Turin, Italy; Onassis Hospital, Athens, Greece; University Hospital, London, Canada; University of Insubria, Varese, Italy.