Accessory Atrioventricular Pathways and Atrioventricular Nodal Reentrant Tachycardia in Teenagers
Electrophysiologic Characteristics and Radiofrequency Catheter Ablation

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SUMMARY
Accessory pathway-mediated tachyarrhythmias and AV nodal reentrant tachycardia represent a large portion of supraventricular tachycardia in younger patients. Reports comparing electrophysiologic characteristics and results of radiofrequency ablation between teenagers and adults from the same electrophysiology laboratory are rare, and these deserve further study. This study included 49 teenage patients (mean age 17 ± 3 years, range from 10 to 20) and 1008 adult patients (mean age 50 ± 13 years, range from 21 to 92) referred for electrophysiologic study and radiofrequency ablation for treatment of accessory pathway-mediated and AV nodal reentrant tachycardia. The results showed that: (1) mean duration of tachyarrhythmia was shorter in teenagers, but incidences of syncope, cardioversion for hemodynamic compromise and associated cardiovascular diseases were similar in both groups; (2) teenagers had a higher incidence of right-sided free wall accessory pathways (34.1% vs 14.9%, p = 0.048) and better conduction properties of accessory pathways and AV nodal pathways; (3) fast-slow and multiple forms of AV nodal reentrant tachycardia were significantly less frequent (p = 0.026) in teenagers, whereas atrial fibrillation with ventricular preexcitation was common in adults; (4) success rate, incidence of recurrent tachycardia, total procedure time, radiation exposure time and number of radiofrequency pulses for successful ablation did not differ significantly between teenagers and adults. In conclusion: (1) different electrophysiologic characteristics were found between teenagers and adults; and (2) radiofrequency ablation was effective and safe in teenagers with paroxysmal
ACCESSORY pathway-mediated tachyarrhythmias and AV nodal reentrant tachycardia represent a large portion of supraventricular tachycardia in younger patients. In recent years, use of radiofrequency catheter ablation for interruption of the accessory pathway and modification of the slow AV nodal pathway has become the treatment of choice in adult patients with drug refractory Wolff-Parkinson-White syndrome and AV nodal reentrant tachycardia, respectively. Initial results using radiofrequency ablation in children and adolescents were excellent, and the complication rate was low. However, possible arrhythmogenicity was suggested because of small heart size and continuous cardiac growth in these young patients. Furthermore, the anatomic substrates and electrophysiologic properties of supraventricular tachyarrhythmia in these young patients might differ from those in adults, and deserve detailed study.

This study reports (1) experience in using radiofrequency catheter ablation for the management of symptomatic supraventricular tachyarrhythmia in teenagers, and (2) comparisons of electrophysiologic characteristics and results of radiofrequency ablation between teenagers and adults studied in the same electrophysiology laboratory.

MATERIALS AND METHODS

Patient characteristics: From May 1990 to August 1994, 1057 patients were referred to this institution for electrophysiologic study and radiofrequency ablation for treatment of accessory pathway-mediated and AV nodal reentrant tachycardia. There were 49 teenage patients (26 males and 23 females), with a mean age of 17 ± 3 years (range 10 to <20 years). Nine (18.3%) patients had other associated cardiovascular diseases, including six with mitral valve prolapse, one with atrial septal defect, one with supravalvular aortic stenosis, and one with a fistula from the left superior vena cava (SVC) to the coronary sinus (CS) associated with a right atrium-left ventricular communication. Four (8.2%) patients had a history of tachyarrhythmia-related syncope. The mean history of tachyarrhythmias was 5 ± 3 years. Patients had been treated with a mean of 3 ± 1 antiarrhythmic drugs which were either ineffective or not tolerated. There were 1008 adult patients (549 males and 459 females) who were designated as a comparison group; their mean age was 50 ± 13 years (range 21 to 92 years).

Baseline electrophysiological study: All procedures were performed in the same electrophysiology laboratory after informed written consent had been obtained; the details of electrophysiologic study in our laboratory have been de-
scribed previously.\textsuperscript{15,16} In brief, three multipolar catheters (inter-electrode space 2 mm, Mansfield-Webster) were introduced from the femoral veins and placed in the right atrium, His bundle area and right ventricle for recording and stimulation. One or two orthogonal electrode catheters (Mansfield-Webster) or other multipolar catheters (USCI, Elecath) used for coronary sinus recording were percutaneously introduced into the jugular vein and placed in the coronary sinus to record the left atrial activation. Intracardiac electrograms were simultaneously displayed with surface electrocardiographic leads I, II and V\textsubscript{1} on a multichannel oscilloscopic recorder (Electronics for Medicine, VR-13) and were recorded at a paper speed of 100–150 mm/second using a filter frequency setting of 30 to 500 Hz. A programmed digital stimulator (Bloom and Associates) was used to deliver electrical impulses of 2.0 ms at approximately twice diastolic threshold. Programmed electrical stimulation consisting of atrial and ventricular incremental pacing and extrastimulation (in steps of 10 msec) was performed to assess the conduction properties of the atrium, ventricle, AV node and AV accessory pathway (antegrade and/or retrograde) and to induce tachycardia. If programmed electrical stimulation failed to induce tachycardia, isoproterenol (at graded dosages from 1 to 4 μg/min) or atropine (0.01 mg/kg) was infused intravenously to facilitate induction of tachycardia. Various types of supraventricular tachycardia were defined by classical criteria.\textsuperscript{17}

\textbf{Endocardial mapping and radiofrequency catheter ablation technique:} These techniques have been well described previously.\textsuperscript{15,16} In brief, a multipolar electrode catheter with a deflectable, large-tip electrode (7 Fr; length 4 mm; Mansfield-Webster) was used for mapping and ablation. Radiofrequency current (continuous-wave, 500 KHz) was generated by an electrosurgical generator (Radinics, model RFG–3C, Burlington, MA, USA). Real-time monitoring of root-mean-square voltage, current and impedance was provided. Radiofrequency current was usually delivered between the tip electrode and a standard adhesive electrosurgical dispersive pad (3 M, Medical and Surgical Division) applied to the posterior chest wall.

For the right free-wall accessory pathway, the tip electrode was positioned against the atrial aspect of the tricuspid annulus (all from the femoral vein approach). For the left free-wall accessory pathway, the tip electrode was positioned against the mitral annulus, beneath (from retrograde ventricular approach) or above the leaflet (through a patent foramen ovale, transseptal approach or retrograde ventricular approach). For the right posteroseptal accessory pathway, the tip electrode (4 or 8 pole electrode catheter) was positioned against the posteroseptal aspect of the tricuspid annulus or around the coronary sinus orifice (from the femoral vein approach); for the left posteroseptal accessory pathways, the tip electrode was positioned against the posteroseptal aspect of the mitral
annulus, beneath or above the leaflet (from the retrograde ventricular approach or the transseptal approach). For the right anteroseptal and midseptal accessory pathways, the tip electrode (8-pole electrode catheter) was positioned against the right wall of the atrial septum (from the femoral vein approach). The presumed ablation sites for accessory pathways showed typical AV fusion with ventricular activation preceding the delta wave, typical VA fusion with earliest retrograde atrial activation or a possible accessory pathway activation potential. For the slow pathway, the tip electrode was positioned along the tricuspid annulus (from posterior approach). The presumed ablation sites for the slow pathway showed a fractionated local atrial electrogram with A/V ratio less than 1 or a possible slow pathway activation potential. Energy (20 to 50 watts for accessory pathways; 30–40 watts for slow pathway) was usually applied during sinus rhythm, ventricular pacing or atrioventricular reentrant tachycardia in patients with accessory pathways and during sinus rhythm or atrial pacing in patients with AV nodal reentrant tachycardia. When accessory pathway conduction was lost within 10 to 15 seconds, the application of energy was maintained for 60 to 120 seconds (longer application time in right-sided accessory pathways). When junctional rhythm was present within 10 seconds during slow pathway ablation, the application of energy was maintained for 20 to 60 seconds. Radiofrequency current was terminated immediately in the event of an increase in impedance, displacement of the ablation catheter or prolongation of PR interval. In most patients, a second application of radiofrequency energy (same power, 30 to 60 seconds) was delivered at the successful ablation site. The end points of ablation procedures were complete elimination of accessory pathway conduction without AV reciprocating tachycardia and modification or elimination of slow pathway conduction without AV nodal reentrant tachycardia. Intravenous heparin in a bolus dose of 5000 U and an infusion of 1000 U per hour were administered to all patients requiring a catheter in the left side of the heart. The total procedure and radiation exposure times were calculated (including the time required to insert and position electrode catheters, time for the diagnostic part of the electrophysiologic study, mapping and ablation procedures; excluding the time required to remove the electrode catheters and vascular sheaths and to obtain hemostasis).

**Postablation monitoring and long-term evaluation:** All patients were monitored in the coronary care unit for 24 hours after the ablation procedures. Serial creatine kinase, creatine kinase MB fraction levels and 12-lead electrocardiograms were measured every 8 hours for 24 hours. Two-dimensional echocardiography was performed one or two days after the ablation procedure in 35 of 49 patients. Patients were encouraged to receive follow-up electrophysiologic study if they had frequent complaints of palpitation after successful ablation. A second ablation session was arranged if the patient had recur-
rent tachycardia. Long-term efficacy was assessed clinically, based on the resting surface electrocardiogram, 24-hour Holter monitoring and clinical symptoms. Each patient came back to the clinic every two weeks in the first month, then every three months in the first year, and every six months in the following years. 

Statistical analysis: All values are expressed as mean ± standard deviation. Comparisons between different groups regarding success, recurrence, and complication rates were obtained with chi-square test with Yates' correction or Fisher exact test; variables of electrophysiologic characteristics and radiofrequency ablation were obtained with Student's t-test. A probability of less than 0.05 was considered statistically significant.

RESULTS

Baseline electrophysiologic characteristics: Among the 49 teenagers, 37 had accessory pathway-mediated tachyarrhythmia and 12 had atrioventricular nodal reentrant tachycardia.

   Among the 37 patients with accessory pathway-mediated tachycardia, 31 patients had a single accessory pathway, and 6 (16.2%) patients had two accessory pathways. Locations of these 43 pathways were 16 (37.2%) in the left-side free wall, 15 (34.9%) in the right-side free wall, 7 (16.3%) in the posteroseptal area and 5 (11.6%) in the anteromidsedtatal area; each of these pathways was subjected to radiofrequency ablation. Two (4.7%) pathways had only antegrade conduction, 24 (55.8%) pathways had only retrograde conduction, and 17 (39.5%) pathways had both antegrade and retrograde conduction. Four (9.3%) pathways had decremental conduction properties. Mean antegrade and retrograde effective refractory periods were 287±62 msec and 250±53 msec, respectively. Orthodromic tachycardia was induced in 35 (94.6%) patients with a mean cycle length of 340±58 msec. Atrial fibrillation was induced in 4 (23.5%) of 17 patients with preexcitation in the 12-lead ECG during sinus rhythm, and the shortest RR interval during atrial fibrillation with ventricular preexcitation was 250±27 ms. Antidromic tachycardia occurred in one patient with one accessory pathway for antegrade conduction and the other accessory pathway for retrograde conduction. Two patients had atrioventricular nodal reentrant tachycardia inducible after successful ablation of the accessory pathway.

   All 12 patients with atrioventricular node reentrant tachycardia had antegrade dual AV nodal pathways and 3 (25%) patients had retrograde dual AV nodal pathways. Mean antegrade and retrograde effective refractory periods of the fast pathway were 282±32 msec and 254±45 msec, respectively. Mean antegrade effective refractory period of the slow pathway was 245±28 msec. Slow-fast form AV nodal reentrant tachycardia was induced in 11 (91.7%) pa-
Patients with a mean cycle length of 327 ± 39 msec; slow-intermediate form AV nodal reentrant tachycardia was induced in one (8.3%) patient with a tachycardia cycle length of 360 msec. None of the patients had fast-slow form AV nodal reentrant tachycardia.

Results and complications of radiofrequency ablation: Overall, successful radiofrequency ablation was achieved in 56 (98.2%) of 57 arrhythmogenic substrates, including 43 accessory pathways and 14 slow AV nodal pathways. Only one right free wall pathway in a patient with left SVC to CS fistula had failed ablation. A median of 7 radiofrequency pulses (range from 1 to 34 pulses, mean 8 ± 7 pulses) were required to successfully eliminate the accessory pathway, and a median of 7 radiofrequency pulses (range 2 to 10 pulses, mean 6 ± 4 pulses) were required to successfully eliminate or modify the slow AV nodal pathway (2 patients had residual slow pathway without AV nodal reentrant echo). Two patients had sustained AV nodal reentrant tachycardia (slow-fast form) after ablation of accessory pathways, and both had successful radiofrequency modification of the slow pathway in the same session. Mean fluoroscopic duration was 34.8 ± 20.2 minutes (range 12 to 120), and mean total procedure time was 2.2 ± 1.1 hours (range 1 to 6). No complication occurred during the ablation procedures.

Post ablation follow-up: The mean follow-up interval was 16 ± 12 months (range 2 to 47 months). Only one patient with an accessory pathway had recurrent supraventricular tachyarrhythmia; a second ablation session achieved a successful result.

Comparisons with adult patients: Two patients with accessory pathway-mediated tachycardia were excluded for comparison because they had AV nodal

| Table 1. Clinical Characteristics of Teenagers (Age < 20 yr) and Adults (Age ≥ 20 yr) with Accessory Pathways and AV Node Reentrant Tachycardia |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Accessory pathways | Age < 20 yr     | Age ≥ 20 yr     | p Value         | AV node reentrant tachycardia | Age < 20 yr | Age ≥ 20 yr | p Value         |
| Age (yr)          | n = 35          | n = 565         |                 | n = 12            | n = 443        |                 |
| Male/Female ratio | 20/15           | 349/216         | 0.714           | 5/7              | 200/243        | 0.956           |
| Duration of tachycardia (yr) | 6 ± 3 | 12 ± 9 | 0.001 | 4 ± 3 | 10 ± 10 | 0.001 |
| History of syncope (%) | 2/35 (5.7) | 44/565 (7.8) | 1.000 | 2/12 (16.7) | 30/443 (6.8) | 0.204 |
| Associated CV diseases | 7/35 (28.6) | 170/565 (30.1) | 0.281 | 2/12 (16.6) | 101/443 (22.8) | 1.000 |
| Hypertension      | 0               | 6               | 0               | 5               |
| Mitral valve prolapse | 5            | 53              | 1               | 30              |
| Ischemic heart disease | 0           | 12              | 0               | 5               |
| Cardiomyopathy     | 0               | 11              | 0               | 5               |
| Rheumatic heart disease | 0           | 6               | 0               | 2               |
| Congenital heart disease | 2           | 13              | 1               | 5               |
| Sick sinus syndrome | 0               | 4               | 0               | 4               |

Values presented are mean ± SD or number (%) of patients. CV = cardiovascular; AV = atrioventricular.
reentrant tachycardia after successful ablation of accessory pathways.

Clinical features (Table I). The mean duration of episodes of palpitation suggestive of tachyarrhythmia was shorter in teenagers (age ≤ 20 years) with accessory pathways or AV nodal reentrant tachycardia. The incidence of tachyarrhythmia-induced syncope and history of cardioversion for tachyarrhythmia-induced severe hypotension was similar in teenagers and adults, independent of the type of tachycardia. The incidence of associated cardiovascular disease was also similar in these two groups of patients. However, teenagers had a higher incidence of mitral valve prolapse and congenital heart disease, and adults had a higher incidence of acquired heart disease.

Electrophysiologic characteristics (Tables II and III). Locations of accessory pathways differed significantly between teenagers and adults (p = 0.049). Teenagers had a slightly higher incidence of right free wall accessory pathways (p = 0.048). The incidence of multiple accessory pathways tended to be higher (p = 0.056), whereas, atrial fibrillation was lower (p = 0.057) in teenagers. Furthermore, inci-
### Table III. Electrophysiologic Characteristics of the Teenagers and Adults with Atrioventricular Node Reentrant Tachycardia (AVNRT)

<table>
<thead>
<tr>
<th></th>
<th>Age &lt; 20 yr (n = 35)</th>
<th>Age ≥ 20 yr (n = 565)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dual pathways</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antegrade</td>
<td>12 (100)</td>
<td>413 (83)</td>
<td>1.000</td>
</tr>
<tr>
<td>Retrograde</td>
<td>3 (25)</td>
<td>94 (21.2)</td>
<td>0.725</td>
</tr>
<tr>
<td><strong>Types of AVNRT</strong></td>
<td></td>
<td></td>
<td>0.026</td>
</tr>
<tr>
<td>Slow-Fast form</td>
<td>11 (91.7)</td>
<td>386 (87.1)</td>
<td>1.000</td>
</tr>
<tr>
<td>Fast-Slow form</td>
<td>0 (0)</td>
<td>12 (2.7)</td>
<td>1.000</td>
</tr>
<tr>
<td>Variant form</td>
<td>1 (8.3)</td>
<td>3 (0.7)</td>
<td>0.102</td>
</tr>
<tr>
<td>Multiple form</td>
<td>0 (0)</td>
<td>42 (9.4)</td>
<td>0.614</td>
</tr>
<tr>
<td><strong>AV 1:1 conduction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast pathway</td>
<td>346 ± 46</td>
<td>389 ± 73</td>
<td>0.025</td>
</tr>
<tr>
<td>Slow pathway</td>
<td>303 ± 35</td>
<td>347 ± 63</td>
<td>0.010</td>
</tr>
<tr>
<td><strong>Antegrade AV Node ERP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast pathway</td>
<td>282 ± 32</td>
<td>318 ± 61</td>
<td>0.025</td>
</tr>
<tr>
<td>Slow pathway</td>
<td>245 ± 28</td>
<td>273 ± 45</td>
<td>0.025</td>
</tr>
<tr>
<td>VA 1:1 conduction</td>
<td>308 ± 51</td>
<td>370 ± 88</td>
<td>0.010</td>
</tr>
<tr>
<td>Retrograde VA ERP</td>
<td>254 ± 45</td>
<td>301 ± 80</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Unless otherwise indicated, values presented are mean ± SD or number (%) of patients. AV = atrioventricular; VA = ventriculoatrial; ERP = effective refractory period.

### Table IV. Biophysical Variables, Results and Complications of Radiofrequency Ablation in Teenagers and Adults

<table>
<thead>
<tr>
<th></th>
<th>Accessory pathways</th>
<th>AVNRT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age &lt; 20 yr (n = 35)</td>
<td>Age ≥ 20 yr (n = 565)</td>
</tr>
<tr>
<td><strong>RF variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse (no.)</td>
<td>8 ± 7</td>
<td>7 ± 6</td>
</tr>
<tr>
<td>Pulse duration (s)</td>
<td>50 ± 19</td>
<td>54 ± 16</td>
</tr>
<tr>
<td>Power (W)</td>
<td>34 ± 8</td>
<td>36 ± 10</td>
</tr>
<tr>
<td>Procedure time (hour)</td>
<td>2.2 ± 1.0</td>
<td>2.3 ± 1.3</td>
</tr>
<tr>
<td>Radiation time (min)</td>
<td>40 ± 18</td>
<td>37 ± 22</td>
</tr>
<tr>
<td>Initial success (%)</td>
<td>34 (97.1)</td>
<td>542 (95.9)</td>
</tr>
<tr>
<td>Final success (%)</td>
<td>34 (97.1)</td>
<td>549 (97.1)</td>
</tr>
<tr>
<td>Recurrent SVT (%)</td>
<td>1 (2.9)</td>
<td>22 (4.0)</td>
</tr>
<tr>
<td>Complications (%)</td>
<td>0 (0)</td>
<td>11 (1.9)</td>
</tr>
</tbody>
</table>

Values presented are mean ± SD or number (%) of patients. AR = aortic regurgitation; AV = atrioventricular; AVNRT = AV node reentrant tachycardia; RF = radiofrequency; SVT = supraventricular tachycardia.
dences of concealed conduction, decremental conduction, exclusively antegrade conduction, orthodromic and antidromic tachycardias were similar in these two groups. The electrophysiologic characteristics of antegrade and retrograde accessory pathways and AV node pathways were significantly poorer in adults. However, no fast-slow form of AV nodal reentrant tachycardia was inducible in teenagers.

Results of radiofrequency ablation (Table IV). The success rate, incidence of recurrent tachycardia, procedure time, radiation exposure time and number of radiofrequency pulses for successful ablation did not differ significantly between teenagers and adults. During the follow-up period, none of the teenagers had any early or late complication. In contrast, 15 of the adults had major or minor complications including 2 cardiac tamponades, 4 AV blocks, one acute aortic regurgitation, 2 aortic dissections, 2 cerebral strokes, 3 femoral artery thromboses and 1 inguinal hematoma.

**DISCUSSION**

**Main finding:** This study found that radiofrequency ablation was effective and safe in teenagers with paroxysmal supraventricular tachycardia. Furthermore, different electrophysiologic characteristics were found between teenagers and adults.

**Accessory pathways in young patients:** Supraventricular tachycardia using an accessory pathway is the most common mechanism of tachyarrhythmia in young patients. The incidence of accessory pathway-mediated tachyarrhythmia was 48% and 73% in Garson’s and Ko’s reports, respectively. In this study, 32 of 49 (65%) patients had accessory pathways, and manifest preexcitation was found in 14 (44%) of 32 patients. Serial studies of the electrocardiogram in young patients with ventricular preexcitation have reported that spontaneous disappearance of the preexcitation pattern occurred in 36% to 50% of young patients. Resolution of preexcitation might be explained by anatomic maturation of the conduction system, the development of adrenergic innervation, a decrease in cholinergic dominance and developmental changes in electrophysiologic properties of accessory AV connections. However, patients who no longer have a ventricular preexcitation pattern may still have attacks of supraventricular tachycardia. It is possible that conversion from a bidirectional to a unidirectional accessory pathway (only from the ventricle to the atrium) might mediate the attack of tachycardia. According to the previous study, if the first episode of supraventricular tachycardia occurred in an infant younger than four to six months of age, the prognosis for complete resolution of supraventricular tachycardia was considerably better than if the supraventricular tachycardia be-
gan in later infancy or childhood; furthermore, among those whose tachycardia was present after five years of age, the tachycardia persisted in 78% of the patients during a mean follow-up period of seven years. In this study, the onset-age of supraventricular tachycardia ranged from 4 to 19 years (mean 11 ± 3 years), and all patients had frequent attacks of tachycardia. This study also showed that the locations of accessory pathways differed between teenagers and adults; right-sided accessory pathways predominated in teenagers. Inducibility of atrioventricular reentrant tachycardia was similar between teenagers and adults, but adults had a slightly higher incidence of atrial fibrillation. This might be explained by the degenerative changes in atria associated with age, more associated cardiovascular disease and increased dispersion of atrial refractoriness. Although Gillette et al had pointed out that the antegrade refractory period of the accessory pathway was longer in children, this study showed the electrophysiologic properties of accessory pathways were better in teenagers; a discrepancy which might have arisen from a different patient population.

**AV nodal reentrant tachycardia in young patients:** Information about AV nodal reentrant tachycardia in children and adolescents is limited. Several studies found that AV nodal reentrant tachycardia occurred in 13% to 20% of young patients (≤ 19 years old) with supraventricular tachycardia. In this study, 12 (24%) of 49 teenage patients had AV nodal reentrant tachycardia including 11 with slow-fast form and 1 with slow-intermediate form. This contrasts with the adult patients, where AV nodal reentrant tachycardia occurred in nearly half of the patients with paroxysmal supraventricular tachycardia. This difference may be because of age-related onset of AV nodal reentrant tachycardia. This study showed that the types of induced AV nodal reentrant tachycardia were significantly different in teenagers and adults (p = 0.0258); this finding might be explained by different AV nodal pathway properties which would evolve as a function of age.

**Radiofrequency catheter ablation in young patients:** Studies of radiofrequency ablation in pediatric patients have shown that the immediate success rate was slightly lower than in adults, and the acute complication rates were acceptably low. However, Park et al reported similar success rates in children, adolescents and adults from the same electrophysiology laboratory by the same group of physicians. The same finding was also demonstrated in this study. We showed that successful radiofrequency ablation was achieved in 56 (98.2%) of 57 arrhythmogenic substrates, and no acute complications occurred during or after the ablation procedures. The first radiofrequency ablation of a right-sided free wall pathway in a teenager was performed after successful ablation of 20 right-sided free wall pathways in adults. The high success rate in this location might be due to more experiences in adults with pathways located in this area.
Several aspects concerning teenagers warranted special consideration: (1) catheter manipulation is more difficult in younger patients, given a small heart size; therefore, use of long vascular sheaths to avoid vascular and myocardial injury during the transseptal approach or retrograde ventricular approach has been suggested; (2) late effects of radiofrequency lesion production in the immature myocardium remain unknown. In experimental studies, radiofrequency lesion formation in the immature myocardium is similar to that in the adult myocardium acutely, but is associated with late lesion enlargement and fibrous tissue invasion of normal myocardium; (3) although the previous study from our laboratory showed that arrhythmogenic effects of radiofrequency ablation were rare in adults, future development of an atrial or ventricular arrhythmogenic substrate in teenagers after ablation was unknown; (4) the risk of radiation exposure for teenagers is somewhat greater because of their somewhat longer life expectancy, and efforts should be made to limit such exposure. Thus, a longer follow-up is required to confirm the safety of radiofrequency catheter ablation in teenagers.

**Study limitations:** Several limitations were found in this study: (1) although these results in teenagers and adults were obtained from the same laboratory, this study group did not include infants and small children, and thus might bias the results; (2) the electrophysiologic parameters were obtained from those pediatric patients who were refractory to or could not tolerate several antiarrhythmic drugs, and thus could not represent the definite characteristics of all pediatric patients; (3) although the mean follow-up period was longer than in several previous reports, a longer follow-up period and regular noninvasive study (echocardiogram and Holter monitoring) would be necessary for those patients with longer procedure and radiation times and more pulse numbers during the ablation session.

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