Anatomically Guided Radiofrequency Catheter Ablation of Atrial Reentrant Tachycardia

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SUMMARY
Atrial reentrant tachycardia (ART) was ablated in an anatomically guided approach. Five patients with ART underwent 2 linear incisions without careful pace or activation mapping. One line was from an atrial activation site earlier than P wave onset to the nearest fixed anatomic conduction barrier, i.e., the inferior vena cava or coronary sinus ostium. The other line was made just above or closely crossed the first line vertically. Mean application time was 29±19 minutes, and the application energy was 14,001±12,322 joules. Mean follow-up after ablation was 15±10 months. Three patients underwent electrophysiologic study three months after and sustained ART was not induced. All patients were free of sustained tachycardia events without antiarrhythmic drugs during the postoperative clinical course. Although anatomically guided ablation for ART requires much time and energy, it is easily and effectively done without careful activation or pace mapping, and is indicated if ablation using activation mapping or entrainment technique fails to cure the ART. (Jpn Heart J 1998; 39: 631–637)

Key words: Atrial reentrant tachycardia, Radiofrequency catheter ablation, Anatomical approach, Linear incision

CATHETER ablation using activation mapping or an entrainment technique in atrial reentrant tachycardia (ART) has low success and a high recurrence rate.1) Common atrial flutter is ablated anatomically by simply interrupting the narrow isthmus conduction between the tricuspid valve and inferior vena cava or coronary sinus ostium, without careful pace or activation mapping. Area or tissue size is required to maintain reentry.2) We theorized that making linear incisions around the slow conduction area, which reduces tissue size with-
out the need for careful pace or activation mapping, could ameliorate or terminate ART.

**Subjects and Methods**

**Subjects:** The subjects were 5 patients (4 women and 1 men from 31 to 72 years old) with symptomatic supraventricular tachycardia resistant to antiarrhythmic drug therapy. All presented a long RP' tachycardia. Associated diseases included mitral valve stenosis in 1, chronic renal failure in 1 who had undergone artificial hemodialysis, and WPW syndrome in 1. The other 2 patients had no underlying disease.

**Method:** *Electrophysiologic study.* After receiving written, informed consent, all patients underwent electrophysiologic study during fasting and mild sedation with oral diazepam. All antiarrhythmic drugs were discontinued five half-lives or more before each study. A 5F quadripolar electrode catheter (Vygon, Aachen, Germany) was introduced percutaneously into the femoral vein and advanced to the high right atrium to record an intracardiac electrogram or stimulate the right atrium. A 6F hexapolar electrode catheter (Vygon) was advanced to the His bundle to record the intracardiac electrogram. A 5F bipolar electrode catheter (Baxter, Irvine, CA, USA) was advanced to the right ventricular apex to stimulate the right ventricle. A 6F hexapolar electrode catheter (Vygon) was introduced into the right antecubital or subclavian vein and positioned in the coronary sinus. A surface electrocardiogram (lead I, aVF, V1) and intracardiac electrogram were simultaneously displayed on a multichannel monitor (Cardiolab, Prucka Engineering Inc., Houston, TX, USA). Electrical stimulation was provided by an electrical stimulator (SEC-3102 Nihon Koden Inc., Japan). Electrical stimulation protocols were atrial single, double, and triple extra-stimuli following an 8 beat drive train at a basic cycle of 600 and 500 ms and atrial burst pacing from 100 to 250 bpm. Tachycardia was diagnosed as reported elsewhere. After supraventricular tachycardia was defined as ART, ablation was performed.

**RF ablation.** A 7F deflectable quadripolar electrode catheter (Cordis Webster, Baldwin Park, CA, USA) was introduced via femoral vein and activation mapping done. When an activation site earlier than P wave onset during ART was defined, two linear incisions were made. One linear incision was made from the earlier activation site to the fixed anatomical conduction barrier, i.e., inferior vena cava or coronary sinus ostium, and the other line was chosen just above or closely crossing the first line vertically (Figure). Radiofrequency energy with a 500 kHz continuous unmodulated current (NL-50I, Central Industry, Chiba, Japan) was delivered at 20 to 25 watts for 30 to 60 seconds between the distal large-tip electrode and an adhesive electrosurgical dispersive pad on the back. Pro-
grammed electrical stimulation to induce ART was repeated after two lines were made. The end point of the procedure was to eliminate ART induction or make ART non-sustaining.

**Follow-up.** Three patients underwent electrophysiologic study 3 months after the procedure. All patients underwent 24-hour ambulatory Holter monitoring repeatedly to determine tachycardia occurrence.

**RESULTS**

**Electrophysiologic study:** Supraventricular tachycardia was induced repeatedly by atrial extra-stimuli in all five patients, all of whom had a shorter A-H interval than the H-A interval during tachycardia. In patients 1, 2, 3, and 5, tachycardia sustained despite atrioventricular block. The earliest atrial activation site was the low lateral right atrium in 1, and low septal right atrium in 4. Although patient 5 had antegrade accessory pathway conduction, ventriculoatrial conduction via an accessory pathway was not observed. The morphology of her tachycardia showed a narrow QRS pattern without a delta wave, not a wide QRS delta pattern. The atrial preexcitation phenomenon was not observed when
Table I. The Ablation Lines in the 5 Patients

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Earliest activation site</th>
<th>Incision lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LLRA</td>
<td>LLRA<del>IVC, LLRA</del>LSRA</td>
</tr>
<tr>
<td>2</td>
<td>LSRA</td>
<td>LSRA<del>IVC, LSRA</del>LLRA</td>
</tr>
<tr>
<td>3</td>
<td>LSRA</td>
<td>LSRA<del>IVC, LSRA</del>CS ostium</td>
</tr>
<tr>
<td>4</td>
<td>LSRA</td>
<td>LSRA<del>IVC, LSRA</del>LLRA</td>
</tr>
<tr>
<td>5</td>
<td>LSRA</td>
<td>CS ostium<del>IVC, CS ostium</del>TV</td>
</tr>
</tbody>
</table>

LLRA = low lateral right atrium; LSRA = low septal right atrium; IVC = inferior vena cava; CS = coronary sinus; TV = tricuspid valve.

Table II. The Conditions of Radiofrequency Ablation in the 5 Patients

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Application time</th>
<th>Total applied energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>12,417</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>3,315</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>35,078</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
<td>11,547</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>7,650</td>
</tr>
</tbody>
</table>

mean: 28 ± 19 14,001 ± 12,322

A ventricular single stimulus was given at the His bundle refractoriness in all cases. In patients 1, 2, 3, and 5, tachycardia was sustained despite atrioventricular block. No evidence of atrioventricular nodal dual pathway was found in any patient. Patients 1, 2, 3, and 4 did not have retrograde V-A conduction. In patient 5, the atrial activation sequence during tachycardia differed from that during ventricular pacing.

Ablation procedure: Two lines were made as described above. In patient 1, ablation lines were from the low lateral right atrium to the inferior vena cava and from the low lateral right atrium to the low septal right atrium. In patients 2 and 4, lines were made from the low septal right atrium to the inferior vena cava and from the low septal right atrium to the low lateral right atrium. In patient 3, lines were made from the low septal right atrium to the inferior vena cava and from the low septal right atrium to the coronary sinus ostium. In patient 5, lines were made from coronary sinus ostium to the inferior vena cava and from the coronary sinus ostium to the tricuspid valve (Table I). ART was not induced immediately after ablation in patients 3, 4 or 5. In patient 2, ART was induced but not sustained. In patient 1, sustained ART was reinduced immediately after the procedure. The total application time ranged from 9 to 50 (28 ± 19) minutes, and the total application energy ranged from 3,315 to 35,078 (14,001 ± 12,322) joules (Table II). There were no complications, such as pericardial effusion, atrioventricular block, or an increase in serum CK.
Follow-up (Table III): Patients 2, 3, and 5 underwent electrophysiologic study 3 months after ablation. In patients 3 and 5, ART was not induced by electrical stimuli, and in patient 2 another form of ART which had a different activation sequence of atrium was induced. All patients had undergone 12-lead electrocardiogram and Holter ambulatory monitoring in follow-up. Follow-up ranged from 3 to 30 months (mean 15 ± 10 months). No patient had sustained tachycardia recurrence without antiarrhythmic agents. Patients 1, 2, and 4 experienced nonsustained tachycardia, though they all had a sustained tachycardia event before ablation.

**DISCUSSION**

**Tachycardia mechanisms:** Reentry, abnormal automaticity and triggered activity caused by delayed afterdepolarization are thought to be responsible for atrial tachycardia.4-6 In our five patients, all tachycardia was induced reproducibly and terminated by programmed electrical stimulation, so we assumed that its mechanism was not automaticity or triggered activity, but rather reentry. To define reentrant long RP' tachycardia as ART, orthodromic atrioventricular reentrant tachycardia (AVRT) with slow accessory pathway conduction, uncommon atrioventricular nodal reentrant tachycardia (AVNRT), and sinus node reentrant tachycardia should be ruled out. Sinus node tachycardia was easily ruled out by observing the atrial activation sequence during tachycardia, which differed from that of sinus rhythm. AVRT with slow accessory pathway conduction was ruled out because single ventricular premature pacing at His bundle refractory timing during tachycardia failed to advance or delay the next atrial electrogram. In patients 1, 2, 3, and 5, tachycardia was sustained despite atrioventricular block, which could not come out in AVRT. Uncommon AVNRT is difficult to distinguish from ART with a low septal right atrium origin. In patient 1, the earliest activation site of the atrium during tachycardia was the low lateral right atrium, i.e., this tachycardia was not due to uncommon AVNRT. Patients 2 to 5...
showed no evidence of a dual AV nodal pathway. Patients 1, 2, 3, and 4 showed no V-A conduction. In patient 5, the atrial activation sequence during ventricular pacing differed from the atrial activation sequence during tachycardia. These findings suggest that these tachycardias were not due to uncommon AVNRT,3,7) so we diagnosed these tachycardias as ART.

Ablation: ART, a common complication in patients after cardiac surgery, occurs in about 25% of patients after the repair of congenital or acquired heart disease.1,8-10) Preliminary reports suggest that ART associated with surgical repair may be amenable to radiofrequency catheter ablation.11,12) Previous reports emphasized the importance of identifying slow conduction regions by using an entrainment technique.1,11-14) Anatomic obstacles in creating protected zones were necessary for maintaining ART.15,16) Baker et al. demonstrated the efficacy of anatomically guided radiofrequency catheter ablation for ART,17) designating radiofrequency lesions where the narrowest isthmus of conducting tissue occurred between a surgical scar and an anatomic barrier. Our method requires simple activation mapping to investigate the early atrial site that precedes P wave onset during ART. No detailed mapping is required to see the slow conduction zone or isthmus, so it is easily and quickly done. The acute success rate was reported to be high, about 77 to 100%, with an electrophysiologic approach,11-14) and 93% with an anatomical approach.17) ART was successfully ablated in 4 of 5 (80%) patients in our study, equally effective as previous reports. Recurrence ranged from 0 to 60% with an electrophysiologic approach,11,11-14) and 14% with an anatomical approach.17) Although our recurrence rate was 60%, which was high compared to the previous studies, recurrent tachycardia was not sustained and self-terminated without medical treatment, though they had sustained and non self-terminated before ablation.

Limitations: Although our method is based on the theory that reentry cannot be maintained by decreasing tissue size,2) we did not assess whether atrial muscle around the reentry core was completely ablated. In a narrow isthmus conduction block of common atrial flutter, the anatomical block line is easily estimated by pacing from the low lateral right atrium and the coronary sinus ostium to see how the activation pattern differs from that before ablation. In ART, linear incisions were made in the right atrial free wall, not in the narrow isthmus, so the change of activation pattern before and after the ablation was difficult to find using a small number of mapping electrodes in the right atrium. Because the endocardial atrium was not smooth, it is difficult to make a perfect block line in these areas, meaning the ablated lesion may have discontinuity.

Second, our approach required much application time and energy, although no complications occurred after the procedure. We hope to make the line block more efficient.
Third, all tachycardia originated in the low right atrium, so we made one line from the low lateral or low septal atrium to the inferior vena cava. We have not approached anatomical ablation for ART with a high right atrium or left atrium origin, and we are not sure where to make the linear incision, e.g., from the early activation sequence of the atrium to the superior vena cava, inferior vena cava, or coronary sinus ostium, pulmonary vein, etc.

**Conclusion:** We have shown that ART is ablated without careful activation mapping or identifying the slow conduction region. Tissue size reduction by making linear incisions is simple and quick for ART ablation.

**REFERENCES**