Radiofrequency Catheter Ablation
of the Atrioventricular Junction
From the Left Ventricle

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Background. The purpose of this study was to describe a new technique for catheter ablation of the atrioventricular junction using radiofrequency energy delivered in the left ventricle.

Methods and Results. Catheter ablation of the atrioventricular (AV) junction using a catheter positioned across the tricuspid annulus was unsuccessful in eight patients with a mean ± SD age of 51 ± 19 years who had AV nodal reentry tachycardia (three patients), orthodromic tachycardia using a concealed midseptal accessory pathway, atrial tachycardia, atrial flutter (two patients), or atrial fibrillation. Before attempts at catheter ablation of the AV junction, each patient had been refractory to pharmacological therapy, and four had failed attempts at either catheter modification of the AV node using radiofrequency energy or surgical and catheter ablation of the accessory pathway. Conventional right-sided catheter ablation of the AV junction using radiofrequency energy in six patients and both radiofrequency energy and direct current shocks in two patients was ineffective. The mean amplitude of the His bundle potential recorded at the tricuspid annulus at the sites of unsuccessful AV junction ablation was 0.1 ± 0.08 mV, with a maximum His amplitude of 0.03–0.28 mV. A 7F deflectable-tip quadripolar electrode catheter with a 4-mm distal electrode was positioned against the upper left ventricular septum using a retrograde aortic approach from the femoral artery. Third-degree AV block was induced in each of the eight patients with 20–36 W applied for 15–30 seconds. The His bundle potential at the sites of successful AV junction ablation ranged from 0.06 to 0.99 mV, with a mean of 0.27±0.32 mV. There was no rise in the creatine kinase-MB fraction and no complications occurred. An intrinsic escape rhythm of 30–60 beats/min was present in seven of the eight patients. Each patient received a permanent pacemaker and has been asymptomatic during 3–13 months of follow-up.

Conclusions. Catheter ablation of the AV junction can be achieved effectively and safely using radiofrequency energy delivered in the left ventricle when the conventional right-sided approach is unsuccessful. (Circulation 1991;84:567–571)

Catheter ablation of the atrioventricular (AV) junction is a well established therapeutic option in selected patients with supraventricular tachycardia refractory to pharmacological therapy. As initially described, this technique used direct-current shocks delivered through a catheter positioned across the tricuspid annulus. The available data indicate that the technique is effective in completely interrupting AV conduction in 70–90% of patients. More recently, radiofrequency energy has been used to ablate AV conduction, and the success rate has been equal to or greater than that achieved with high-voltage shocks. Nevertheless, there remains a minority of patients in whom AV block cannot be induced with these techniques.

The purpose of this report is to describe a new technique for catheter ablation of the AV junction using radiofrequency energy delivered in the left ventricle. This technique was used in eight consecutive patients with drug-refractory supraventricular tachycardia in whom the conventional right-sided approach failed to induce AV block.

Methods

Characteristics of Patients

The subjects of this report were three men and five women with a mean ± SD age of 51 ± 19 years who had
highly symptomatic supraventricular tachycardia refractory to pharmacological therapy. Each patient had a history of frequent episodes of palpitations associated with dizziness, chest pain, or syncope. Symptoms had been present for 9.8±10 years. Six patients had no evidence of structural heart disease, one had undergone implantation of a Bjork-Shiley mitral valve 9 years earlier, and the other had hypertrophic cardiomyopathy. A mean of 3.8±1.5 drugs had been ineffective or discontinued due to side effects.

The mechanism of tachycardia was found to be atypical AV nodal reentry at cycle lengths of 290 and 320 msec and atrial flutter at a cycle length of 220 msec with 2:1 AV conduction in two patients each; typical AV nodal reentry at a cycle length of 300 msec, orthodromic tachycardia at a cycle length of 300 msec using a concealed midseptal accessory pathway, atrial tachycardia at cycle lengths of 300–380 msec, and atrial fibrillation with a rapid ventricular response was present in one patient each.

The three patients who had AV nodal reentry had undergone unsuccessful attempts at AV node modification with radiofrequency energy using a technique already described.9 Two of these patients had also undergone an unsuccessful attempt at AV junction ablation using direct-current shocks of 200 and 300 J. The patient with orthodromic tachycardia had previously undergone unsuccessful attempts at surgical division and radiofrequency catheter ablation of the accessory pathway.

The eight subjects included in this report were among 70 consecutive patients in whom AV junction ablation was attempted at our institution between March 1990 and February 1991.

Catheter Ablation Technique

The ablation procedures were performed after informed consent was obtained under a protocol approved by the human research committee at the University of Michigan. Midazolam was used as needed for sedation. Two 6Fr quadripolar catheters were inserted into a femoral vein and positioned across the tricuspid annulus and in the right ventricle. A 5Fr bipolar catheter was inserted into the right internal jugular vein and positioned in the right ventricular apex for temporary pacing. A catheter was placed in the femoral artery for continuous monitoring of blood pressure. A 2,000-unit bolus of heparin was infused after positioning the catheters. An additional 3,000-unit bolus followed by a 1,000-unit bolus every hour was administered after insertion of the catheter into the left ventricle.

Radiofrequency energy at a frequency of 350 kHz was delivered as a continuous unmodulated sine wave from an electrosurgical unit (model RFG-3B, Radionics, Burlington, Vt.). The catheter used for delivering the radiofrequency current was a 7Fr quadripolar catheter with a 4-mm tip electrode, an inter-electrode spacing of 5 mm, and a deflectable curve (Mansfield-Webster, Watertown, Mass.). Radiofrequency current was delivered between the tip electrode and an indifferent cutaneous patch electrode (Valleylab, Boulder, Colo.). The intracardiac electrograms were filtered at 50–500 Hz and recorded on a Mingograf 7 recorder (Siemens-Elema).

Applications of radiofrequency energy consisted of 20–36 W delivered for 15–60 seconds. If AV block was not produced, the catheter was repositioned. If there was an abrupt fall in current caused by a rise in impedance, energy application was discontinued, the catheter was withdrawn, adherent coagulum was removed, and the catheter was repositioned. If third-degree AV block occurred during an energy application, the energy was delivered for an additional 30 minutes. If atrioventricular block persisted for 15 minutes, the session was concluded.

All patients underwent an attempt at ablation of the AV junction using a conventional right-sided approach. The ablation catheter was positioned across the tricuspid valve to record the largest possible bipolar atrial and His bundle potentials with the distal electrodes. In each patient, the conventional right-sided approach was unsuccessful. A mean of 9.6±4 applications of radiofrequency energy (range, 5–17) were delivered to at least four different sites without successful ablation of AV conduction. Three patients developed a first-degree AV block and six patients developed a right bundle branch block during these unsuccessful attempts at ablation.

During the same session (six patients) or another session (two patients), the ablation catheter was introduced into a femoral artery and advanced into the left ventricle. Using the left anterior oblique projection, the tip of the ablation catheter was positioned against the interventricular septum to record the largest possible His bundle potential from the distal electrodes (see Figure 1).

All patients underwent permanent pacemaker implantation the next day. The plasma concentration of creatine kinase and its MB fraction were measured at 8-hour intervals for 24 hours. An echocardiogram was obtained after the procedure. The intrinsic escape rhythm was evaluated 15 minutes after the procedure, 2 days later, and every 3 months in an outpatient clinic. The pacing rate was reduced to 30 pulses/min for 1 minute; if an escape rhythm was not observed, pacing was suspended for 7 or 8 seconds.

Statistical Analysis

Continuous variables are expressed as mean±SD. Comparisons were performed with Student’s t test. A probability value of less than 0.05 was considered significant.

Results

Effects of Radiofrequency Energy

Third-degree AV block was induced in each of the eight patients with the application of radiofrequency energy in the left ventricle. A mean of 3.6±3.2 applications of energy were required (range, 1–11).
Sousa Radiofrequency Catheter Ablation

FIGURE 1. Fluoroscopic views of catheter position for AV junction ablation from the left ventricle. Upper panel: LAO 35° projection; lower panel: RAO 35° projection. The ablation catheter is positioned against the left ventricular septum. A catheter in the standard right-sided His bundle position is also shown. A temporary pacing catheter is in the right ventricle apex. HBE, His bundle electrogram; HRA, high right atrium; LAO, left anterior oblique projection; LV SEPTUM, left ventricle septum; RAO, right anterior oblique projection; RVA, right ventricle apex.

Fifteen minutes after ablation of AV conduction, an intrinsic escape rhythm with a mean rate of 44±10 beats/min (range, 30–60) was present in seven patients. The escape rhythm was junctional in five patients and idioventricular in two. One patient had no escape rhythm.

FIGURE 2. His bundle electrograms recorded in patient 2 with a catheter positioned across the tricuspid annulus (upper panel) and against the left ventricular septum (lower panel). The right-sided His bundle electrogram shows the largest His bundle potential (0.28 mV) that could be recorded at the tricuspid annulus. Multiple attempts at catheter ablation of AV conduction at this site were unsuccessful. The His bundle potential recorded in the left ventricle had an amplitude of 0.99 mV. Complete AV block was induced by a single application of radiofrequency energy at this site.

Electrogram Characteristics

The electrograms recorded in the left ventricle were characterized by the presence of a large His bundle potential, a relatively small atrial electrogram amplitude, and an AV ratio of less than 1 (see Figure 2 and Table 1).

The mean His bundle potential at sites of energy delivery was significantly larger with the left ventricular approach (0.25±0.29 mV) than with the right-sided approach (0.1±0.08 mV) (p<0.001; see Table 1). However, the largest mean His bundle potential recorded at the tricuspid annulus (0.19±0.1 mV) was not significantly different in amplitude than the successful mean His bundle potential recorded in the left ventricle (0.27±0.32 mV) (see Table 1).

Complications

During the applications of radiofrequency energy, there were occasional premature ventricular depolarizations. However, no patient had sustained ventricular tachycardia. There were no changes in blood pressure during the application of radiofrequency energy. The creatine kinase and MB fraction concentration remained within the normal range in all patients.
TABLE 1. Electrogram Amplitudes and Results of Ablation

<table>
<thead>
<tr>
<th>Patient</th>
<th>Right-sided approach</th>
<th>Left ventricular approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RF applications (n)</td>
<td>RF applications (n)</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
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</tr>
<tr>
<td>2</td>
<td>7</td>
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</tr>
<tr>
<td>3</td>
<td>17†</td>
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</tr>
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<tr>
<td>7</td>
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<td>4</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Mean±SD</td>
<td>9.6±4</td>
<td>4±4‡</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean His* potential (mV)</th>
<th>Max His potential (mV)</th>
<th>A:V Effect</th>
<th>RF amplitude (mV)</th>
<th>Successful His potential (mV)</th>
<th>Escape rhythm</th>
<th>Escape rate (beats/min)</th>
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<tbody>
<tr>
<td>1</td>
<td>0.04±0.03</td>
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<td>0.6</td>
<td>RBBB</td>
<td>0.48</td>
<td>Nodal</td>
<td>40</td>
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<tr>
<td>2</td>
<td>0.18±0.07</td>
<td>0.28</td>
<td>0.3</td>
<td>1°AVB, RBBB</td>
<td>0.99</td>
<td>Nodal</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
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<td>0.25</td>
<td>0.8</td>
<td>RBBB</td>
<td>0.5±0.3</td>
<td>Nodal</td>
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<tr>
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<td>0.02</td>
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<td>0.06±0.01</td>
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<tr>
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<td>0.22</td>
<td>0.2</td>
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<td>0.16±0.11</td>
<td>Vent</td>
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<tr>
<td>8</td>
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<td>0.18</td>
<td>0.1</td>
<td>None</td>
<td>0.14±0.05</td>
<td>Nodal</td>
<td>60</td>
</tr>
</tbody>
</table>

RF, radiofrequency energy; A:V, mean ratio of the amplitudes of the atrial and ventricular electrograms; RBBB, complete right bundle branch block; 1°AVB, first-degree atrioventricular block; Vent, idioventricular escape rhythm.

*Mean of His electrograms at each site that ablation was attempted.
†Patients who also underwent attempts at ablation with electric shocks.
§Not significantly different compared with right-sided approach.
||Not significantly different from the maximum His bundle potential recorded with the right-sided approach.

Echocardiograms demonstrated no new valvular abnormalities, wall motion defects, or pericardial effusions.

**Follow-up**

All patients have remained in third-degree AV block during a mean follow-up of 6±3.8 months (range, 3–13 months). Seven patients had escape rhythms with rates of 35–60 beats/min; the patient who did not have an escape rhythm 15 minutes after induction of AV block continued to have no evidence of an escape rhythm during follow-up.

**Discussion**

**Main Findings**

This study demonstrates the feasibility of ablating AV conduction using radiofrequency energy delivered in the left ventricle. The technique was successful in each of eight patients with refractory supraventricular tachycardia in whom a conventional approach with a catheter across the tricuspid valve had failed to produce AV block. The His bundle potentials recorded in the left ventricle were generally larger than those recorded in the standard position across the tricuspid annulus. There were no complications related to the procedure, and all eight patients have remained in complete AV block during 3–13 months of follow-up.

**Efficacy of Right-Sided Catheter Ablation of the AV Junction**

The eight patients in this report in whom radiofrequency ablation of the AV junction with a catheter positioned across the tricuspid annulus was ineffective were part of a group of 70 patients who underwent this procedure, representing a failure rate of 11%. This compares favorably with the previously reported success rates of 46–92% for radiofrequency catheter ablation of the AV junction using a conventional right-sided approach.6–8 Of note is that four of the eight patients had undergone previous attempts at AV node modification or septal accessory pathway ablation; this may have contributed to the inefficacy of the conventional right-sided approach, possibly because of residual edema or fibrosis in the region surrounding the AV node. In the patient who had a hypertrophic cardiomyopathy, it is possible that the conventional approach to catheter ablation failed because of an increased distance between the catheter tip and the conduction tissue resulting from hypertrophy of the septum. Nevertheless, AV conduction was successfully ablated in each of the eight patients when a left ventricular approach was used.

**Level of AV Block**

During the unsuccessful attempts at right-sided ablation, six of eight patients developed right bundle branch block and three had first-degree AV block. Therefore, a cumulative effect on the AV junction from the prior right-sided ablation attempts or preferential damage to the left bundle from the left-sided ablation cannot be excluded. The presence of a junctional escape in five of eight patients, the absence of a right bundle branch block in two patients, and the recording of a distinct His potential and the absence of a left bundle potential at the effective target sites in each patient favor a proximal lesion in the conduction system. This is consistent with the results of previous histological studies that have described the location of the penetrating bundle to be on the left side of the interventricular septum.10

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Clinical Implications

In the majority of patients with supraventricular tachycardia refractory to pharmacological therapy who are appropriate candidates for catheter ablation of the AV junction, complete AV block can be successfully induced by delivering either direct-current shocks or radiofrequency energy through a catheter positioned across the tricuspid valve. In the minority of patients in whom this conventional approach is ineffective, the therapeutic options for inducing complete AV block have included intraoperative cryoablation of the AV node/His bundle axis or chemical ablation of AV conduction. However, intraoperative cryoablation requires a thoracotomy, and chemical ablation requires cannulation of the AV nodal branch of the right coronary artery and intracoronary injection of ethanol and is associated with a risk of inferior myocardial infarction. Compared with these techniques, catheter ablation of AV conduction using radiofrequency energy delivered in the left ventricle is a relatively simple and safe method for creating AV block when the conventional right-sided technique of catheter ablation is ineffective.

References

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**Key Words** • catheter ablation • radiofrequency energy • atrioventricular block • Brief Rapid Communication
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