Clinical Investigation

Long-term Results of Catheter Ablation of a Posteroseptal Accessory Atrioventricular Connection in 48 Patients

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Forty-eight patients with a posteroseptal accessory atrioventricular (AV) connection underwent catheter ablation of the accessory AV connection with 200–400 J shocks delivered by a standard defibrillator. Cathodal shocks were delivered through the proximal pair of electrodes of a 6F quadrupolar electrode catheter positioned in the coronary sinus such that the proximal electrodes straddled the ostium (12 patients) or the third electrode from the tip was at the ostium (36 patients). A 16-cm patch electrode positioned on the back or anterior chest served as the anode. Two to 4 shocks were delivered (total, 635±198 J, mean±SD). The catheter ablation procedure was clinically successful in eliminating symptomatic tachycardias in 32 of 48 patients (67%) during a mean follow-up of 26±19 months. A long-term follow-up electrophysiology study was performed in 27 of the 32 patients who had a successful clinical outcome, and this showed that conduction through the accessory AV connection was completely absent in 25 patients and present but impaired in two patients. The success rate was significantly higher in patients with a concealed accessory AV connection (13 of 13, 100%) than in patients with manifest preexcitation (19 of 35, 54%; p<0.001). Among the 12 patients in whom the proximal electrodes of the ablation catheter straddled the ostium of the coronary sinus, one patient developed cardiac tamponade requiring needle pericardiocentesis; there were no instances of cardiac tamponade among the 36 patients in whom the third electrode from the tip was at the ostium of the coronary sinus. Other complications were AV block requiring a permanent pacemaker and transient atrial tachycardia in one patient each and an asymptomatic pericardial effusion in three patients. In conclusion, with the catheter ablation technique described in this study, a successful clinical outcome may be achieved in approximately two thirds of patients who have a posteroseptal accessory AV connection, and the risk of serious complications is low. This technique is particularly well suited to patients with a concealed posteroseptal accessory AV connection, in whom the success rate is higher than in patients with manifest preexcitation. (Circulation 1989;79:1160–1170)

Initial reports based on small numbers of patients suggested that transcatheter direct-current shocks were capable of successfully ablating a posteroseptal accessory atrioventricular (AV) connection with a low risk of serious complications.1–5 In a more recent study that included 17 patients with a posteroseptal accessory AV connection, the success rate of catheter ablation was 65%; however, there was an 18% incidence of coronary sinus perforation and cardiac tamponade.6 Therefore, the overall value of catheter ablation of a posteroseptal accessory AV connection as an alternative to surgical ablative techniques has been unclear.

The purpose of the present report is to describe the results and complications of catheter ablation of a posteroseptal accessory AV connection with direct-current shocks in a consecutive series of 48 patients. These data should allow for a more accurate comparison of the efficacy and risk of a

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catheter technique for ablating posteroseptal accessory AV connections relative to the efficacy and risks of surgical techniques.

Methods

Characteristics of Patients

Forty-eight consecutive patients with a posteroseptal accessory AV connection and symptomatic tachycardias underwent an attempt at catheter ablation at the University of California, San Francisco, and the University of Michigan between August 1984 and September 1988. The duration of follow-up was a minimum of 4 months in each patient. There were 24 women and 24 men, and their mean age was 33±12 years (±SD; range, 15–68 years). Forty-four patients had no evidence of structural heart disease; three patients had a dilated cardiomyopathy with a left ventricular ejection fraction of 0.25–0.35; and one patient had coronary artery disease and a left ventricular ejection fraction of 0.35.

Documented spontaneous arrhythmias had occurred in each patient and included orthodromic reciprocating tachycardia in 42 patients, atrial fibrillation with a rapid ventricular response in 24 patients, and the permanent form of junctional reciprocating tachycardia using a concealed, slowing conducting posteroseptal accessory AV connection in four patients. Forty-four patients had been treated with a mean of 2.1±1.6 antiarrhythmic drugs that were either ineffective or not tolerated; four patients did not undergo trials of antiarrhythmic drug therapy before the attempted ablation.

The posteroseptal accessory AV connection was capable of both anterograde and retrograde conduction in 35 patients and was concealed in 13 patients. A second accessory AV connection was present in the right free wall in three patients and in the left free wall in one patient. The first eight patients in this series were the subjects of earlier reports.1,3

In 47 of 48 patients, the accessory AV connection was identified as being posteroseptal in location by detailed mapping of the atrial activation sequence in the right atrium and coronary sinus during orthodromic reciprocating tachycardia. In each of these patients, the site of earliest atrial activation during orthodromic reciprocating tachycardia was at the ostium of the coronary sinus. In one patient who had persistent atrial fibrillation, intraoperative mapping of the ventricular activation sequence during atrial fibrillation was performed at the time of an attempt at surgical division of the accessory AV connection. Intraoperative mapping showed that the site of earliest ventricular activation in this patient was in the posterior septum. Catheter ablation was attempted in this patient after two unsuccessful attempts at surgical ablation.

Electrophysiologic Testing

A detailed electrophysiology study was performed in each patient before catheter ablation. The electrophysiology studies were performed while patients were in the fasting, unsedated state, after informed consent was obtained, and at least four half-lives after discontinuing treatment with antiarrhythmic drugs. Electrode catheters were introduced into a femoral and subclavian vein and positioned in the right atrium, His bundle position, right ventricular apex, and coronary sinus. Electrocardiographic leads V1, I, and III and the intracardiac electrograms were displayed on an oscilloscope and recorded at a paper speed of 100 mm/sec on an Electronics-for-Medicine VR 12 (Pleasantville, New York) of Siemens-Elema Mingograf 7 recorder (Solna, Sweden). Pacing was performed with a programmable stimulator (Bloom Associates, Narbeth, Pennsylvania). The pacing stimuli had a duration of 2 msec and a current strength of twice the late diastolic threshold.

Protocol for Catheter Ablation

If the initial electrophysiology study showed the presence of a posteroseptal accessory AV connection and if the patient was deemed to be an appropriate candidate for ablative therapy, the alternatives of surgical and catheter ablation were discussed at length with the patient. If the patient opted for catheter ablation, informed consent was obtained under an investigational protocol approved by the Human Research Committee at the University of California, San Francisco and the University of Michigan.

The patient was brought to the electrophysiology laboratory in the fasting state, and electrode catheters inserted into a femoral vein were positioned in the right atrium, His bundle position, and right ventricular apex. A short 5F cannula was inserted into a femoral artery to allow continuous monitoring of the arterial pressure.

An electrode catheter that had a central lumen was inserted into a subclavian or internal jugular vein and positioned within the coronary sinus. Contrast material was injected manually into the coronary sinus to visualize the position of the ostium relative to anatomic landmarks such as vertebral bodies and ribs. Mapping then was repeated to confirm that the earliest atrial activation during orthodromic reciprocating tachycardia was at the ostium of the coronary sinus. If this was the case, the central lumen catheter was removed and replaced with a previously unused 6F quadripolar electrode catheter (USCI, Billerica, Massachusetts) (standard production, 1 cm interelectrode distance).

In the first 12 patients of this series, the catheter in the coronary sinus was positioned such that the proximal pair of electrodes straddled the ostium of the coronary sinus. This technique was modified slightly after the 12th patient in the series developed coronary sinus perforation and cardiac tamponade upon delivery of a shock through the proximal pair of electrodes. To minimize the risk of coronary sinus perforation in subsequent patients, the catheter was positioned such that the third electrode
from the tip (electrode number 3) was either at or slightly outside the ostium of the coronary sinus.

The proximal two electrodes (numbers 3 and 4) of the quadripolar catheter in the coronary sinus were made electrically common and connected to the cathodal output of a defibrillator (PhysioControl Life-Pak 6, Redmond, Washington, or Air Shields, Hatboro, Pennsylvania) by the use of an adaptor cable. A 16-cm patch electrode (R2 Corporation, Skokie, Illinois) positioned either on the anterior chest (13 patients) or on the back (35 patients) served as the anode. An electrode catheter at the right ventricular apex was used for temporary pacing in the event of AV block after delivery of the shocks. The patient was anesthetized with sodium thiopental or methohexital, and a shock ranging from 200 to 400 J in stored energy was delivered. The shocks had a damped sinusoidal waveform. In two patients who developed either cardiac tamponade or persistent AV block after the first shock, only one shock was delivered. If the first shock was successful in eliminating conduction through the accessory AV connection, a second shock was delivered in the same manner 10–15 minutes later to minimize the possibility that conduction through the accessory AV connection might later return. If conduction through the accessory AV connection was present at 10–15 minutes after the first shock, up to two additional shocks were delivered. In six patients in whom conduction through the accessory AV connection initially was eliminated but then returned within several days or weeks after the first ablation attempt, an additional two shocks were delivered during a second procedure.

Postshock Monitoring and Evaluation

The patients were monitored in the Coronary Care Unit for 24 hours after the ablation procedure, then underwent continuous electrocardiographic monitoring for 4–6 additional days. Serial measurements of the creatine kinase MB fraction were obtained. A technetium pyrophosphate scintigram was performed 2–4 days after the catheter ablation procedure in the first 15 patients of this series. In each patient, a two-dimensional echocardiogram was obtained within 5 days after the procedure.

Long-term Evaluation of Efficacy

A follow-up electrophysiology study was performed in the electrophysiology laboratory 3–8 months after the ablation procedure in 34 patients to determine the long-term effects of the transcatheter shocks on anterograde and retrograde conduction through the posteroseptal accessory AV connection. An intraoperative electrophysiology study was performed to evaluate the long-term effects of the ablative shocks in an additional eight patients who underwent surgery either because the catheter ablation procedure was unsuccessful or because of a second accessory AV connection.

Long-term efficacy was assessed only on a clinical basis in four patients with manifest ventricular preexcitation who declined a follow-up electrophysiology study; the long-term efficacy of the ablation procedure in these patients was assessed clinically based on the electrocardiogram and clinical symptoms. Each of these patients had prominent delta waves on their baseline electrocardiograms and frequent episodes of symptomatic tachycardia before the ablation procedure.

One patient with a concealed accessory AV connection and frequent episodes of symptomatic tachycardia underwent a follow-up electrophysiology test 1 week after the ablation procedure but declined a long-term follow-up study; assessment of long-term efficacy was based only on the absence of symptomatic tachycardia during 27 months of follow-up. A follow-up electrophysiology study to assess long-term efficacy also was not performed in a patient with permanent junctional reciprocating tachycardia who remained in sinus rhythm after the ablation procedure.

Follow-up Angiographic Studies

Coronary angiography was performed at the time of the follow-up electrophysiology study 4–6 months after the catheter ablation procedure in 10 patients. The coronary sinus was visualized angiographically in 24 patients either by injection of contrast material directly into the coronary sinus or during the venous phase of coronary angiography.

Statistical Analyses

Continuous variables in the patients in whom catheter ablation was and was not successful were compared by Student’s t test. The success rates in patients who had concealed and manifest accessory AV connections were compared by Fisher’s exact test. The effects of the transcatheter shocks on the AV junction were assessed with a paired t test. However, the properties of the AV junction at baseline and after ablation could not be compared in every patient either because of the presence of ventricular preexcitation or persistent atrial fibrillation, because the AV node effective refractory period was longer than the effective refractory period of the accessory AV connection or shorter than the atrial functional refractory period, or because an electrophysiology test was not performed after ablation. A p value less than 0.05 was considered significant.

Results

Patients With Manifest Preexcitation

The catheter ablation procedure was successful in eliminating or impairing conduction over the posteroseptal accessory AV connection such that there were no recurrences of symptomatic tachycardia in 19 of 35 patients (54%) with manifest ventricular preexcitation. Each of these 19 patients
TABLE 1. Catheter Ablation in Patients With Manifest Ventricular Preexcitation

<table>
<thead>
<tr>
<th>Patient</th>
<th>Shocks (n)</th>
<th>Joules</th>
<th>Long-term effect on AAVC conduction</th>
<th>Follow-up (mo)</th>
<th>Clinical success</th>
<th>Additional therapy</th>
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<td>1</td>
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<td>66</td>
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</tr>
<tr>
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<td>Surgical ablation*†</td>
</tr>
<tr>
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<td>62</td>
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<td>61</td>
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<td>Nadolol</td>
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<tr>
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<tr>
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<td>300</td>
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<td>15</td>
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<td>AVJA‡</td>
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<tr>
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<td>600</td>
<td>No change</td>
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<tr>
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<td>Slowed</td>
<td>9</td>
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</tr>
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<tr>
<td>29</td>
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<td>31</td>
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<tr>
<td>33</td>
<td>4§</td>
<td>1,100</td>
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<td>Flecainide</td>
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<td>34</td>
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<td>No change</td>
<td>4</td>
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<td>Flecainide</td>
</tr>
<tr>
<td>35</td>
<td>2</td>
<td>500</td>
<td>Eliminated</td>
<td>4</td>
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</table>

AAVC, accessory atrioventricular (AV) connection; AVJA, AV junction ablation; NA, not assessed by electrophysiologic testing.
*Surgical ablation of a second accessory AV connection in the right free wall.
†Surgical ablation of the posteroseptal accessory AV connection.
‡Performed because of persistent atrial tachycardia or atrial fibrillation with rapid conduction through the AV junction.
§Two sessions.
|| No return of delta waves on electrocardiogram.

has not been treated with antiarrhythmic drugs and has remained free of symptomatic tachycardias involving the posteroseptal accessory AV connection during a mean follow-up interval of 27±20 months.

The number of shocks and total number of joules delivered and the long-term response are described for each patient in Table 1. Fourteen of the 19 patients with a successful clinical outcome underwent a long-term electrophysiology test that showed the complete elimination of anterograde and retrograde conduction through the posteroseptal accessory AV connection. Two patients with a successful clinical outcome underwent a long-term electrophysiology test that showed that conduction through the accessory AV connection was present but impaired. In patient 3, anterograde conduction was slowed compared with conduction at baseline, but retrograde conduction over the accessory AV connection was eliminated, and therefore orthodromic reciprocating tachycardia was not inducible. In patient 26, the baseline anterograde and retrograde
block cycle lengths in the accessory AV connection were 240 and 220 msec, respectively; the long-term follow-up electrophysiology test showed lengthening of the block cycle length to 300 msec in both directions. Short episodes of nonsustained orthodromic reciprocating tachycardia were inductive by programmed electrical stimulation, with spontaneous termination by block in the accessory AV connection; however, during infusion of isoproterenol, orthodromic tachycardia was not inducible. This patient had had an average of 1 episode/wk of sustained tachycardia before the ablation procedure and has had no episodes of symptomatic tachycardia during 7 months of follow-up.

In three of 19 patients with a successful clinical outcome, a long-term electrophysiology test was not performed. These patients had no evidence of ventricular preexcitation on serial electrocardiograms and no symptoms of tachycardia during follow-up.

The catheter ablation procedure was unsuccessful in 16 of 35 patients. In each of these 16 patients, conduction through the posteroseptal accessory AV connection disappeared upon delivery of the shocks. In five patients, conduction through the accessory AV connection returned within 10 minutes. Among the other eleven patients, conduction returned within 24 hours in four patients, within 2 days in two patients, within 3, 6, and 10 days in one patient each, and within 60 days after the ablation procedure in two patients. Follow-up evaluation showed no impairment of conduction through the accessory AV connection in 14 patients, absent retrograde conduction with no impairment of anterograde conduction in one patient, and mild slowing of conduction in one patient. Four patients underwent successful surgical ablation of the posteroseptal accessory AV connection; 10 patients have been treated with antiarrhythmic drugs; and two patients have not required therapy because the episodes of tachycardia have been very brief.

### Patients With Concealed Accessory AV Connections

The catheter ablation procedure was successful in each of the 13 patients who had a concealed posteroseptal accessory AV connection. The number of shocks, total joules delivered, and long-term response are described for each patient in Table 2. Among the 11 patients who underwent a long-term follow-up electrophysiology study, each had no evidence of conduction through the accessory AV connection. Patient 43, who did not undergo a long-term follow-up electrophysiology test, underwent electrophysiologic testing 1 week after the ablation procedure and had no evidence of conduction through the posteroseptal accessory AV connection; he had no symptomatic arrhythmias during 29 months of follow-up. Patient 45, who also did not undergo a long-term follow-up electrophysiology test, had permanent junctional reciprocating tachycardia baseline and has remained in sinus rhythm during 14 months of follow-up.

Four patients underwent successful surgical ablation of a right or left free wall accessory AV connection after the catheter ablation procedure. None of the 13 patients has been treated with antiarrhythmic drugs, and each has remained free of symptomatic tachycardias during a mean follow-up interval of 30±13 months.

### Factors Associated With Outcome

The success rate in patients who had a concealed posteroseptal accessory AV connection (13 of 13, 100%) was significantly higher than in patients with

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### Table 2. Catheter Ablation in Patients With Concealed Accessory Atrioventricular Connections

<table>
<thead>
<tr>
<th>Patient</th>
<th>Shocks (n)</th>
<th>Joules</th>
<th>Long-term effect on AAVC conduction</th>
<th>Follow-up (mo)</th>
<th>Clinical success</th>
<th>Additional therapy</th>
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<tr>
<td>36</td>
<td>2</td>
<td>800</td>
<td>Eliminated</td>
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<td>4</td>
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AAVC, accessory atrioventricular connection; NA, not assessed by electrophysiologic testing.

*Surgical ablation of a second accessory atrioventricular connection in the left or right free wall.

†Permanent junctional reciprocating tachycardia.

‡Complete atrioventricular block occurred as a complication of catheter ablation, but the patient already had a permanent pacemaker for preexisting sick sinus syndrome.
TABLE 3. Comparison of Patients in Whom Catheter Ablation Was Successful and Unsuccessful

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Successful</th>
<th>Unsuccessful*</th>
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<tbody>
<tr>
<td>VA interval at os of coronary sinus (msec)†</td>
<td>98±19</td>
<td>102±21</td>
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<td>1:1 AV conduction (msec)‡</td>
<td>286±41</td>
<td>270±30</td>
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<tr>
<td>1:1 VA conduction (msec)§</td>
<td>282±30</td>
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<tr>
<td>Total Joules</td>
<td>609±175</td>
<td>688±236</td>
</tr>
<tr>
<td>Peak creatine kinase MB (IU/l)</td>
<td>22±8</td>
<td>25±13</td>
</tr>
</tbody>
</table>

All values are mean±SD; n=32 patients for the successful group; n=16 patients for the unsuccessful group.
VA, ventriculoatrial; AV, atrioventricular.
†No significant differences were found in the parameters listed between patients with a successful and unsuccessful outcome.
‡Ventriculoatrial interval during orthodromic reciprocating tachycardia (excluding four patients with permanent junctional reciprocating tachycardia).
§Shortest atrial pacing cycle length associated with 1:1 atrioventricular conduction through the posteroventricular accessory atrioventricular connection.
§Shortest ventricular pacing cycle length associated with 1:1 ventriculoatrial conduction through the posteroventricular accessory atrioventricular connection.

manifest preexcitation through the posteroventricular accessory AV connection (19 of 35, 54%; p<0.001).

A comparison of the 32 patients in whom the catheter ablation procedure was clinically successful and the 16 patients in whom the procedure was ineffective is presented in Table 3. There were no significant differences between the two groups of patients in mean age, the ventriculoatrial conduction time at the ostium of the coronary sinus during orthodromic tachycardia (excluding the four patients with permanent junctional reciprocating tachycardia), the shortest pacing cycle length associated with 1:1 anterograde or retrograde conduction through the posteroventricular accessory AV connection, the total number of joules delivered, or the peak creatine kinase MB fraction.

The success rate in 13 patients in whom the anode was positioned on the anterior chest was not significantly different than in 35 patients in whom the anode was positioned on the back (77% vs. 63%, respectively).

The 75% success rate among 12 patients in whom the electrodes used to deliver the shocks straddled the ostium did not differ significantly from the 64% success rate among 36 patients in whom electrode 3 was at the ostium.

Complications

Patient 12 developed cardiac tamponade after receiving one shock of 300 J through two electrodes 1 cm apart that straddled the ostium of the coronary sinus. A hemorrhagic pericardial effusion was aspirated by needle pericardiocentesis, with resolution of the tamponade and no reaccumulation of a pericardial effusion during 24 hours of monitoring. This patient was the only patient in whom a previously used electrode catheter inadvertently was used for the ablation procedure, and inspection of the catheter afterward showed two grossly visible breaks in the insulation of the catheter. The patient underwent elective surgical ablation of the posteroseptal accessory AV connection 1 month later, at which time a healed perforation of the coronary sinus was observed 2 cm from the ostium.

There were no other instances of cardiac tamponade after the catheter ablation procedure. However, an echocardiogram 2–3 days after the procedure showed a small posterior pericardial effusion in three patients who were asymptomatic.

Patient 40 developed high degree AV block with a narrow QRS escape after receiving two 300-J shocks with the anode placed on the anterior chest. This patient already had a permanent pacemaker because of a preexisting sick sinus syndrome. Transient AV nodal block was observed in all patients, usually resolving within 10 minutes. Five patients had Mobitz I or third degree AV nodal block lasting up to 24 hours; however, AV block resolved in each of these patients, and a permanent pacemaker was not needed. Four of 12 patients (33%) developed transient AV block lasting more than 10 minutes when the anode was positioned on the anterior chest compared with one of 36 patients (3%) when the anode was on the back (p<0.05). No patient developed a bundle branch block.

The mean peak creatine kinase MB fraction after the catheter ablation procedure was 23±11 IU/l (normal, 0–10 IU/l). Among the 15 patients in whom a technetium pyrophosphate scintigram was obtained after the ablation procedure, the results of scintigrams were normal in 14 patients, and only in one patient was there focal uptake in the lateral wall of the left ventricle. Electrocardiograms did not show new pathologic Q waves, and echocardiograms did not show new wall motion abnormalities in any of the patients.

New ventricular arrhythmias were not observed in any patient. Patient 28 experienced symptomatic nonsustained atrial tachycardia, rates 130–170 beats/min, after the catheter ablation procedure. Atrial tachycardia had never been documented before the ablation procedure. This patient was treated with flecainide for 1 month and then had no further recurrences of symptomatic tachycardia. A follow-up electrophysiology test 3 months later showed no inducible atrial tachycardia. Patient 16 experienced occasional atrial fibrillation before the ablation procedure and continued to have paroxysmal atrial fibrillation afterward. She has been treated with digoxin and has an average ventricular rate of 70 beats/min during atrial fibrillation. The catheter ablation procedure was successful in eliminating conduction through the accessory AV connection in both of these patients.

Coronary angiography was performed 4–6 months after the ablation procedure in 10 patients who did not have structural heart disease, and it showed no coronary artery abnormalities. No abnormalities of the coronary sinus were seen in the 24 patients in
TABLE 4. Comparison of the Atrioventricular Junction Baseline and 3–8 Months After Ablation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n</th>
<th>Baseline</th>
<th>After ablation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH Interval (msec)</td>
<td>26</td>
<td>92±44</td>
<td>93±45</td>
</tr>
<tr>
<td>HV Interval (msec)†</td>
<td>38</td>
<td>45±5</td>
<td>42±4</td>
</tr>
<tr>
<td>Block cycle length (msec)‡</td>
<td>11</td>
<td>348±88</td>
<td>353±84</td>
</tr>
<tr>
<td>AV Node ERP (msec)</td>
<td>10</td>
<td>322±40</td>
<td>328±51</td>
</tr>
</tbody>
</table>

All values are mean±SD.

AH, atrial-His; HV, His-ventricular; AV, atrioventricular; ERP, effective refractory period.

†There were no significant differences between the values at baseline and after ablation for the parameters listed.

‡In the absence of ventricular preexcitation.

§Determined at basic drive cycle length 500 msec.

whom the coronary sinus was visualized angiographically.

Among the eight patients who underwent surgical ablation of an accessory AV connection either because catheter ablation of the posteroseptal accessory AV connection was ineffective or because the patient had a second accessory AV connection, a 0.5-cm² endocardial ecchymosis was observed at the ostium of the coronary sinus in two patients. There were no grossly visible sequelae of the ablative shocks in the remaining six patients.

Intraoperative Mapping

Four patients in whom the catheter ablation procedure was unsuccessful underwent surgical ablation of the posteroseptal accessory AV connection. Mapping of the ventricular insertion of the posteroseptal accessory AV connection was performed in patient 2; however, mapping of the atrial insertion was not possible because retrograde conduction through the posteroseptal accessory AV connection was absent. Manipulation of the heart in patient 8 resulted in complete loss of conduction through the posteroseptal accessory AV connection, and therefore, no intraoperative mapping was possible. This patient underwent extensive dissection in the posterior septum unguided by mapping.

In patients 9 and 11, epicardial mapping showed that the earliest atrial activation during orthodromic reciprocating tachycardia occurred 1–2 cm to the left of the crux; the ventriculatoarial interval at this epicardial site was 10–20 msec shorter than the ventriculotoarial interval measured at the ostium of the coronary sinus.

Long-term Effects on the AV Junction

The AH interval, HV interval, shortest atrial pacing cycle length associated with 1:1 conduction through the AV junction, and the AV node effective refractory period could be compared in the baseline state and 3–8 months after the catheter ablation procedure in 11 to 38 patients (Table 4). There were no significant differences in these variables before and after the attempted ablation.

Discussion

Comparison of Catheter and Surgical Ablation

With the catheter ablation technique described in this report, a successful clinical outcome may be achieved in approximately two thirds of patients who have a posteroseptal accessory AV connection. Although there is a risk of coronary sinus perforation, persistent AV block and new atrial arrhythmias when defibrillator pulses are delivered in the vicinity of the ostium of the coronary sinus, the risk of each of these complications appears to be less than 3%.

Surgical ablation of posteroseptal accessory AV connections in the past was associated with less satisfactory results than when the accessory AV connection was in the left or right free wall. However, the endocardial and epicardial approaches for surgical ablation of posteroseptal accessory AV connections have been refined, and both techniques currently are reported to be nearly 100% effective. Therefore, surgical ablation techniques clearly are more often curative than the catheter ablation technique described in this report. Nonetheless, surgical ablation is associated not only with the discomfort of a sternotomy, but also with complications that may include postcardiotomy syndrome (7%), temporary ventricular dysfunction and low output state (4–6%), atrial arrhythmias (4%), permanent complete AV block (1%), and postoperative hemorrhage (1%). Although the operative mortality rate in recent series has been zero, death is also a possible complication of cardiac surgery.

The 67% success rate achieved in this series and the relatively low risk of serious complications suggest that it may be appropriate to first attempt catheter ablation in patients with a posteroseptal AV connection who are appropriate candidates for ablative therapy, reserving surgical ablation for those patients in whom the catheter ablation procedure is not effective. In this way, the morbidity and discomfort of a sternotomy and the risks of cardiac surgery may be avoided in a significant proportion of patients.

Factors Affecting Outcome

The only identifiable factor that was associated with the outcome of the ablation procedure in this series was whether the posteroseptal accessory AV connection was concealed or associated with manifest preexcitation. The success rate was 100% among the 13 patients who had a concealed posteroseptal accessory AV connection compared with 54% among the 35 patients in whom the accessory AV connection was associated with manifest ventricular preexcitation. Although the explanation for this observation is unknown, these data suggest the possibility that concealed posteroseptal accessory AV connections may be more discrete or may be located in closer proximity to the ostium of the coronary sinus compared with overt posteroseptal accessory AV connections.
Bardy et al\textsuperscript{6} reported that the success rate of catheter ablation of posteroseptal accessory AV connections was related to the ventriculoatrial interval during orthodromic reciprocating tachycardia; a local ventriculoatrial interval less than 80 msec was associated with a higher success rate than when the ventriculoatrial interval was more than 80 msec.\textsuperscript{6} This finding was not confirmed in the present series, in which there was not a significant difference in the ventriculoatrial interval at the coronary sinus ostium during orthodromic reciprocating tachycardia between patients in whom the ablation procedure was successful and those in whom it was not.

\textit{Intraoperative Mapping}

The results of intraoperative mapping in two patients who underwent surgical ablation of a posteroseptal accessory AV connection after unsuccessful attempts at catheter ablation may be helpful in explaining why shocks delivered at the ostium of the coronary sinus may have failed to ablate the accessory AV connection. In these two patients, epicardial and endocardial mapping during orthodromic reciprocating tachycardia showed that the ventriculoatrial interval recorded on the epicardium just to the left of the crux was 10–20 msec shorter than the ventriculoatrial interval recorded at the ostium of the coronary sinus. This observation suggests that the ablation technique used in this report was unsuccessful in some patients because the accessory AV connection in these patients may have been closer to the epicardium than to the endocardium or that the atrial insertion of the accessory AV connection may have been in the left side of the posterior septum instead of near the ostium of the coronary sinus. Because intraoperative mapping data are not available in patients in whom catheter ablation was curative, the relation between the results of epicardial and endocardial mapping and the outcome of the ablation procedure remains conjectural.

Ruder et al\textsuperscript{10} reported that unsuccessful attempts at catheter ablation of a posteroseptal accessory AV connection were associated with loss of large, discrete atrial electrograms, making subsequent intraoperative mapping more difficult. In contrast, a reduction in the size of the atrial electrograms recorded near the ostium of the coronary sinus was not observed in the patients in this series who underwent unsuccessful attempts at catheter ablation.

\textit{Electrode Configuration Used for Ablation}

Two adjacent electrodes were made electrically common and used as the cathode. This dual electrode configuration was used to deliver the shocks over a larger surface area, thereby increasing the likelihood of successful ablation of the accessory AV connection. Another advantage of using two electrodes as the cathode is that the resultant increase in electrode surface area is associated with a decrease in bubble formation, arcing, and barotrauma.\textsuperscript{11}

Anodal shocks result in a greater amount of bubble formation and barotrauma than do cathodal shocks.\textsuperscript{11,12} Therefore, to minimize the risk of barotrauma-induced complications, only cathodal shocks were used in this series.

\textit{Damage to the Coronary Sinus}

An important determinant of the risk of coronary sinus perforation during catheter ablation of a posteroseptal accessory AV connection may be the position of the electrodes used to deliver the ablative shocks. In the first 12 patients in this series, shocks were delivered through two electrodes that straddled the ostium of the coronary sinus. Because of coronary sinus perforation in a patient in whom this technique was used, the technique was modified so that neither electrode would be within the coronary sinus. With this modification in technique, no further instances of cardiac tamponade occurred in the next 36 patients. Based on this experience, and in light of the known risk of coronary sinus perforation when shocks are delivered within the coronary sinus,\textsuperscript{13,14} it would appear important to visualize the location of the ostium angiographically and to avoid delivering shocks within the coronary sinus.

Of note, the only instance of cardiac tamponade in this series occurred in a patient in whom the catheter used to deliver the ablative shocks was not a new one. Because the insulation in this catheter was not intact, a breakdown in dielectric strength possibly resulted in the unintended delivery of energy to the distal electrode positioned within the coronary sinus. A prior study has in fact shown that a breakdown in dielectric strength may result in the delivery of energy to unintended target sites.\textsuperscript{15} The apparent location of the perforation 2 cm within the coronary sinus is consistent with the possibility that energy was delivered through the distal electrode. An alternative explanation for cardiac tamponade in this patient is that there was mechanical perforation of the coronary sinus by the tip of the electrode catheter, which has been reported previously as a complication of catheter ablation of the AV junction.\textsuperscript{16}

Although only one patient developed cardiac tamponade, echocardiography showed that three additional patients had a small posterior pericardial effusion that was not hemodynamically significant. Bardy et al\textsuperscript{6} also observed a small and hemodynamically insignificant pericardial effusion in five of 19 patients in whom catheter ablation of a posterior accessory AV connection was attempted. It is unclear whether the pericardial effusion in these patients represented a small hemopericardium from perforation of coronary sinus or right ventricle or represented an inflammatory reaction. In any case, because of a risk of coronary sinus or right ventricular perforation, immediate surgical backup should
be available in the event of cardiac tamponade during the catheter ablation procedure.

Risk of Coronary Sinus Perforation in Prior Studies

In the series reported by Bardy et al.,6 14 patients with a posteroseptal accessory AV connection underwent an ablation attempt with an 8F or 8.5F high dielectric strength electrode catheter, and three of these patients developed coronary sinus rupture and required an emergency sternotomy. In the present report by contrast, a 6F electrode catheter was used, and only one of 48 patients experienced coronary sinus rupture and cardiac tamponade. Ruder et al.,10 who also used a 6F electrode catheter, reported that no complications occurred in eight patients who received shocks at the ostium of the coronary sinus. Therefore, the risk of coronary sinus rupture may be related to the size of the ablation catheter. This possibility was suggested by Bardy et al.,6 who found that the ratio of the catheter diameter to the coronary sinus diameter at the ablation site was more than 0.5 in three patients who developed coronary sinus rupture and was always less than 0.5 in patients who did not have this complication. These data suggest that the use of electrode catheters larger than 6F for catheter ablation of posteroseptal accessory AV connections should be avoided.

Another notable difference between the technique used in this report and the technique used by Bardy et al. is that in the latter study, shocks were delivered directly within the coronary sinus. In the present study by contrast, shocks were delivered only in the immediate vicinity of the ostium of the coronary sinus. Delivery of shocks within the coronary sinus may be another factor accounting for the higher incidence of coronary sinus rupture in the series reported by Bardy et al.6

Effects on the AV Junction

Although transient AV block was common upon delivery of shocks at the ostium of the coronary sinus, persistent AV block requiring a permanent pacemaker occurred in only one of 48 patients. Long-term electrophysiologic and clinical evaluations have indicated that there is no long-term impairment of conduction through the AV junction in patients in whom AV block resolves by 24 hours after the ablation procedure. The 2% incidence of persistent AV block in this study compares favorably with the risk of complete AV block associated with surgical ablation of posteroseptal accessory AV connections, which has been reported to range from 1% to 10%,7,8

Comparison of the results obtained with placement of the anode on the back and on the anterior chest suggests that an anterior position of the anode may be associated with a greater depressant effect on the AV junction. On the other hand, the efficacy of the ablation procedure was not affected by the position of the anode. Therefore, to minimize the risk of AV block, it appears preferable to position the anode on the back.

Effects of Shocks on Myocardium and Coronary Arteries

The small rise in the creatine kinase MB fraction and the normal findings of the technetium pyrophosphate scintigram in 14 of 15 patients indicates that shocks delivered at the ostium of the coronary sinus are associated with only a limited amount of myocardial injury.

A proarrhythmic effect of the shocks was manifest in one patient in this series who developed a transient atrial tachycardia after the ablation procedure. Ectopic atrial tachycardia has been previously reported to be a complication of catheter ablation of a posteroseptal accessory AV connection.17 Because only one of 48 patients in this series developed an atrial tachycardia, the risk of this complication appears to be low.

Bardy et al.6 reported that a patient who underwent catheter ablation of a posteroseptal accessory AV connection developed a small posterior left ventricular infarction, possibly caused by spasm of a branch of the right coronary artery. Furthermore, experimental studies have raised a concern that shocks delivered within the coronary sinus may result in intimal hyperplasia in the circumflex coronary artery.13 In the present study, there were no instances of myocardial infarction as a complication of the ablation procedure, and follow-up coronary angiograms in 10 patients showed no gross injury to the coronary arteries. Furthermore, none of the patients who did not have structural heart disease had any clinical manifestation of coronary artery disease during 5 years of follow-up. Nevertheless, it must be acknowledged that long-term deleterious effects of transcatheter shocks on coronary arteries near the coronary sinus ostium cannot yet be ruled out.

Dual Accessory AV Connections

Three patients in this series had a right free wall accessory AV connection in addition to a posteroseptal accessory AV connection. This association between posteroseptal and right free wall accessory AV connections has been observed previously.18 An additional patient had a second accessory AV connection located in the left free wall. Three of these four patients underwent successful catheter ablation of the posteroseptal accessory AV connection but later required surgical ablation of the second accessory AV connection because of persisting tachycardia-related symptoms. Although the catheter procedure in these patients did not obviate the need for an operation, catheter ablation of the posteroseptal accessory AV connection nonetheless had the beneficial effect of simplifying the surgical procedure.
Atrial Fibrillation After Ablation

Sharma et al\textsuperscript{19} showed that surgical ablation of accessory AV connections in patients without structural heart disease prevents further episodes of atrial fibrillation, suggesting that reciprocating tachycardia or ectopy mediated by the accessory AV connection is the mechanism of induction of spontaneous atrial fibrillation in most patients with the Wolff-Parkinson-White syndrome. Similarly, among 12 patients in this series without structural heart disease who had the Wolff-Parkinson-White syndrome and a history of atrial fibrillation and in whom the catheter ablation was successful, only one patient experienced symptomatic atrial fibrillation during a mean follow-up of 36±20 months after the procedure. This finding shows that in patients with the Wolff-Parkinson-White syndrome atrial fibrillation may be prevented not only by surgical ablation of the accessory AV connection but also by catheter ablation.

Limitations

Bardy et al\textsuperscript{6} showed that defibrillator pulses may be short-circuited during attempts at catheter ablation and that this problem can be detected only by oscilloscopic monitoring of voltage and current waveforms. A limitation of the present study is that voltage and current waveforms were not measured. Therefore, it cannot be determined whether the failure to ablate the accessory AV connection in some patients may have been related to inadequate delivery of energy to the target site. However, this possibility seems unlikely because the degree of elevation of the creatine kinase MB fraction was similar in patients in whom the ablation procedure was and was not effective.

Conclusions

In conclusion, catheter ablation of posteroseptal accessory AV connections with the technique described in this report may be a reasonable alternative to surgical ablation. There is a risk of coronary sinus rupture, AV block, and new atrial arrhythmias with the catheter ablation technique, but the risk is low and compares favorably with the risks of surgical ablation. Although the overall success rate is lower with catheter ablation than with operative techniques, successful catheter ablation may obviate the need for a sternotomy in a significant proportion of patients who are candidates for ablative therapy. The catheter technique described herein is particularly well suited to patients who have a concealed posteroseptal accessory AV connection because the success rate in these patients is higher than in patients with manifest preexcitation.

Recently described modifications in defibrillator pulses and in the design of electrode catheters may allow delivery of shocks of sufficient energy to ablate target tissues without the barotrauma associated with standard defibrillator pulses.\textsuperscript{20–22} In addition, radiofrequency and laser energy have been used for ablation of accessory AV connections and also are not associated with barotrauma.\textsuperscript{23,24} It is possible that these newer techniques will improve the efficacy and safety of catheter ablation of posteroseptal and free wall accessory AV connections.

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