Catheter ablation of the atroventricular junction: a report of the percutaneous mapping and ablation registry

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ABSTRACT An international registry was formed to collate data for patients undergoing attempted catheter ablation of the atrioventricular (AV) junction and insertion of a permanent pacemaker. Over the past 2 years, data was submitted for 127 patients who were followed for a mean of 9.9 ± 8.2 months. The most common arrhythmia treated was chronic or paroxysmal atrial fibrillation or flutter (78 patients, 61%); the remainder had supraventricular tachycardia due to AV node reentry, ectopic atrial tachycardia, or incorporated an accessory pathway. A single shock of 150 to 400 J was effective in producing chronic third-degree AV block in 45 patients while two or more shocks were used in an additional 45 patients. There was no significant difference in the total cumulative energy used in successful and unsuccessful procedures. Immediate complications related to the shock included ventricular fibrillation (one patient), pericardial tamponade (one patient), and transient hypotension (one patient). No chronic sequelae occurred as a result of these complications. Late complications (1 day to 1 month) included ventricular tachycardia (three patients), sepsis involving the pacemaker pocket (two patients), staphylococcal sepsis from temporary pacing catheter (one patient), thrombophlebitis (one patient), thrombosis of the left subclavian vein (one patient), and hemothorax (one patient). Follow-up evaluation revealed chronic third degree AV block in 90 (71%) and AV conduction resumed but no drugs were required for arrhythmia control in eight (6.5%) and arrhythmia control was achieved with previously ineffective drugs in 16 (13%). Thirteen patients (10%) had no improvement and five of these patients underwent cardiac electrosurgery for direct His bundle ablation. Three patients died suddenly; four cardiac deaths (severe congestive heart failure which was present prior to ablation) and four noncardiac deaths were reported. In summary, catheter ablation of the AV junction provided good-to-excellent results in terms of arrhythmia control in 90% of patients. This procedure, while preferable to cardiac surgery, must still be considered a procedure of last resort because of the possible complications, induction of a pacemaker dependency state, and the small risk of sudden death.

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PATIENTS with supraventricular tachycardia that proves resistant to drug and/or antitachycardia pacemakers are candidates for direct surgical ablation of the His bundle.1-7 More recently, a closed-chest catheter technique has been devised that allows for ablation of the atroventricular (AV) junction. In brief, the technique involves delivery of one or more synchronized shocks through an electrode catheter close to the His bundle to an electrode patch positioned over the left scapula.8 A number of reports have described use of this technique in man, but these reports concern relatively few patients and include only limited follow-up data.9-13 The purpose of this report is to present data provided to an international voluntary registry that was established approximately 2½ years ago in order to better assess the safety and efficacy of this technique.

Material and methods

Approximately 2½ years ago, the Executive Committee of the Percutaneous Cardiac Mapping and Ablation Registry initiated a standardized approach for patients undergoing catheter ablation of the AV junction. In all patients the electrode(s) showing the largest His bundle deflection was used as the cathode while a plate positioned over the left scapulae was used as the anode. Shocks were delivered from standard direct-current defibrillators to anesthetized patients. In 94% of attempted ablations a No. 6F or No. 7F USCI catheter was used and in 93% of
attempts the distal electrode was used as the cathode. The amount of energy or number of shocks used could not be standardized among the centers since insufficient guidelines existed at the time the registry was initiated.

The existence of an international voluntary registry of patients undergoing attempted catheter ablation of the AV junction was publicized in American and European cardiology journals. Participating centers were sent forms requesting information relative to the type of arrhythmia present, symptoms, prior treatment, presence of organic heart disease, type of catheter used for the procedure, the number of shocks and the energy used, the total peak creatine kinase and peak MB after the shock, and the escape rate of the emerging pacemaker. Since different modes of measurement of creatine kinase and its isoenzymes were used at the various centers, results are expressed in terms of elevation of creatine kinase level above the upper limits of normal for that laboratory. In addition, all complications relating to the procedure were detailed.

Follow-up data were requested at 6 month intervals, with particular attention paid to arrhythmia control and return of AV conduction. In the event of death, further information relative to the nature of the demise was requested. Sudden death was described as that which was abrupt (within minutes of symptoms), unexpected, and of natural causes. Cardiovascular death was defined as that occurring due to cardiac causes and occurring hours after onset of symptoms. In the present study, all cardiovascular deaths were found to be the result of cardiac failure. For purposes of this study, type I drugs were defined as quinidine, procainamide, or disopyramide, calcium-channel blockers included verapamil or diltiazem, and "other experimental drugs" included aprindine, propafenone, ajmaline, and encainide.

Patient follow-up varied somewhat at the various participating centers, but electrocardiograms and/or Holter recordings were obtained 1 to 2 weeks after the procedure and then at least once every 3 months for the first year. In eight centers follow-up included brief pacemaker inhibition to define the escape rate of the pacemaker and native rhythm; in 10 centers, the pacemaker was reprogrammed to its lowest rate, while no change in the paced rhythm was attempted at the remaining centers. All data were entered into a PDP 1123 computer and the relevant data were analyzed by $\chi^2$ or t test or a linear regression analysis, as appropriate for the parameters studied.

Results

The clinical data for 127 patients (collected from 24 centers) who underwent attempted AV junctional ablation are summarized in table 1. These patients frequently had associated organic heart disease that may have played a role in the genesis of symptoms during tachycardia. The most frequent arrhythmia found in these patients was paroxysmal or chronic atrial fibrillation or flutter associated with rapid ventricular response. All patients with paroxysmal supraventricular tachycardia underwent invasive electrophysiologic studies and the mechanisms of their arrhythmias are detailed in table 1. Eighteen percent (14%) had orthodromic AV tachycardia involving a bypass tract: two of these patients had Mahaim tracts while 21 had AV node reentrant arrhythmias. Eleven patients had atrial tachycardia either resulting from interatrial reentry or ectopic atrial tachycardia, while two had the permanent form of junctional reciprocating tachycardia. The most frequent symptom was palpitations, which were observed in 49% of the patients. Sixty-five percent of patients had either frank syncope or dizziness. Twenty percent of patients complained of chest pain that was believed to be atypical for angina pectoris, while 8% had typical anginal pains during episodes of tachycardia.

All patients underwent at least three drug trials and the mean number of failed drug trials, as defined in table 1, was 3.8 trials/patient. The actual number of drugs used was greater since multiple trials of a variety of $\beta$-blockers, type I antiarrhythmic drugs, calcium-channel blockers, or other experimental drugs were frequently used. In over 80% of the patients trials of digitalis, $\beta$-blockers, calcium-channel blockers, or type I drugs failed or they proved intolerant to the drugs. Fifty-six percent proved intolerant to or failed trials of amiodarone (40%) or other experimental drugs (16%). Twelve percent of patients failed trials with permanent antitachycardia pacemakers and in two with the Wolff-Parkinson-White syndrome attempted surgical bypass ablation failed.

### Table 1

**Clinical findings in patients with drug-refractory supraventricular tachycardia**

<table>
<thead>
<tr>
<th>Heart disease (type/% of patients)</th>
<th>Arrhythmia (type/% of patients)</th>
<th>Symptoms (type/% of patients)</th>
<th>Prior treatment (type/% of patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No organic disease/44</td>
<td>Atrial fibrillation/flutter/61</td>
<td>Palpitations/49</td>
<td>Digitalis/83</td>
</tr>
<tr>
<td>Cardiomyopathy/18</td>
<td>Atrioventricular node reentry/17</td>
<td>Dizziness/38</td>
<td>$\beta$-Blockers/83</td>
</tr>
<tr>
<td>Coronary artery disease/17</td>
<td>Accessory pathway/14</td>
<td>Syncope/37</td>
<td>Type 1/82</td>
</tr>
<tr>
<td>Valvular heart disease/11</td>
<td>Atrial tachycardia/9</td>
<td>Dyspnea/33</td>
<td>Calcium-channel blockers/80</td>
</tr>
<tr>
<td>Cor pulmonale/6</td>
<td>Permanent JRT/2</td>
<td>Chest pain/20</td>
<td>Amiodarone/40</td>
</tr>
<tr>
<td>Hypertensive cardiovascular disease/4</td>
<td>Other/2</td>
<td>Fatigue/14</td>
<td>Other experimental drugs/16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Angina/8</td>
<td>Antitachycardia pacemaker/12</td>
</tr>
</tbody>
</table>

The percentages total more than 100% since more than one parameter may have been present in a given patient.

JRT = junctional reciprocating tachycardia.
A USCI No. 6F or No. 7F catheter was used in 87% of the attempted ablations, a specially designed hemi-quadripolar electrode was used in 5%, a Josephson quadripolar electrode catheter was used in 4%, and a variety of other catheters were used in 6%. In some patients requiring additional shocks more than one type of catheter was used. The distal electrode was used for 93% of attempted ablations, a more proximal electrode was used in 15%, and a bipolar configuration was used in 3%.

The mean maximal total level of creatine kinase after delivery of the shocks was $2.3 \pm 0.45$ and the mean maximal creatine kinase MB level was $8.4 \pm 0.38$ greater than the upper limits of normal. In 27 patients no escape rhythm (>5 sec) was present after the shock, while in 76 patients the mean escape rate of the junctional pacemaker was $46.1 \pm 11.9$ beats/min. For 24 patients data on escape rate of the pacemaker were not available.

The number of shocks used and the total energy delivered are summarized in table 2 and figure 1. In 90 patients complete AV block was established and AV conduction returned in 37. In 45 of 90 (50%) successful ablations only one shock (150 to 400 J) was used. Seventy-five of 90 (83%) successful procedures required one to two shocks while three to six shocks were required in the remaining 15 patients. There was no significant difference with respect to either the number of shocks used or cumulative energy delivered between those in whom complete AV block was achieved and those in whom AV conduction returned. Seventy-four of 127 (58%) patients had complete AV block after the first attempt at ablation (which included one or more shocks).

Complications were noted in three patients immediately after delivery of a shock. One patient developed ventricular fibrillation that required external direct-current countershock after a single shock. One patient developed pericardial tamponade that required emergency pericardiocentesis after two shocks of 300 J. One patient developed hypotension lasting 30 min and required an infusion of dopamine for pressure support. No deaths or long-term adverse sequelae were reported as a result of these complications. Nine patients were reported to have other complications from 1 day to 1 month after attempted ablation. Three patients who did not have ventricular arrhythmias before ablation developed these arrhythmias afterward. In one patient the arrhythmia appeared to be related to malposition of the permanent pacemaker catheter. Repositioning of the catheter terminated the arrhythmia and no antiarrhythmic drugs were required over a follow-up period of 18 months. Two additional patients developed increased ventricular ectopy and episodes of ventricular tachycardia that required antiarrhythmic drugs for suppression. Two patients developed sepsis of the permanent pacemaker pocket; in both patients revision of the pacemaker pocket was undertaken since antitachycardia units had been previously implanted.

**Table 2**

<table>
<thead>
<tr>
<th>No. of shocks</th>
<th>Third-degree AV block (n)</th>
<th>Return of AV conduction (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>37</td>
</tr>
</tbody>
</table>
Staphylococcal sepsis in another patient was attributed to the temporary pacemaker catheter. One patient developed thrombosis of the left subclavian vein, which was the site of insertion of the temporary ventricular pacing electrode, while another developed thrombophlebitis of the femoral vein. One patient developed hemothorax that was presumably related to subclavian vein catheterization. One of nine patients with late complications died because of sepsis related to a permanent pacemaker, but no long-term adverse effects were reported for the remainder.

The 127 patients were followed over a mean of 9.9 ± 8.2 months (1 month to 3 years). The follow-up data are summarized in figure 2. Ninety patients (71%) achieved long-term complete AV block and drugs were required in only two patients who developed ventricular arrhythmias after attempted ablation. Eight patients (7%) showed return of AV conduction (often in patients with varying degrees of AV block), but no antiarrhythmic drugs were required for arrhythmia management. In 16 patients (13%) AV conduction and symptomatic arrhythmias that required treatment returned. The procedure clearly failed in 13 (10%) and five of these patients subsequently underwent cardiac electrosurgery for direct His bundle ablation. In one of these five, mention was made that the surgical procedure proved difficult because of difficulty in localizing the His bundle. His bundle sectioning proved effective for control of arrhythmias in all five patients. The remaining eight patients are currently being treated with drugs and repeat catheter or surgical ablation is being contemplated for some of these patients. Eleven patients died during the follow-up period; four deaths were attributed to noncardiac causes and four to cardiac causes (severe congestive heart failure that was present before ablation). Sudden death was reported in three patients. One patient with atrial fibrillation, cor pulmonale, and a history of excess ethanol ingestion died suddenly 1 month after receiving one shock of 300 J. AV conduction returned and he required antiarrhythmic drugs (digitalis, propranolol, and verapamil) for rate control. One patient with a dilated cardiomyopathy died suddenly 6 weeks after receiving two shocks of 500 J. She remained in complete AV block after the shock and had normal pacemaker function 15 min before her demise. One additional patient with a dilated cardiomyopathy and paroxysmal atrial flutter died 4½ months after receiving two shocks of 300 and 400 J.

**Discussion**

The purpose of this report is to provide a clearer assessment of the risks and benefits of a catheter technique for AV junctional ablation. In a group of 127 patients with symptomatic supraventricular tachycardia in whom multiple drug regimens had failed, 98 patients (77%) were believed to have had an excellent response. In these patients, either third-degree AV block was achieved or AV conduction was sufficiently impaired so that control of arrhythmias was possible without the need for drugs. In an additional 16 patients (13%) control was possible after the ablative procedure but antiarrhythmic drugs were required. Our data suggest that the catheter technique provided good-to-excellent results with respect to control of arrhythmias in approximately 90% of patients.

Three patients developed complications that were directly related to the shock. One patient developed pericardial tamponade, but the exact cause of this complication was not determined. Since complete AV block was achieved, it appears unlikely that the shock was delivered to the free wall of the atrium. Conceivably, catheter flaring during shock could have traumatized the right atrial wall. Similarly, the possibility of mechanical perforation of the right ventricle via the temporary pacing catheter cannot be excluded. Ventricular fibrillation was reported in one patient and occurred in spite of proper electrocardiographic synchronization. This complication has been reported in patients undergoing properly synchronized external shock.14–16 Transient hypotension in another patient might have been reflective of myocardial damage, but since the procedure was attended by a minimal creatine kinase MB release a more likely cause is loss of AV synchrony during ventricular pacing in the presence of anesthetic agents. Fortunately, none of these com-

![FIGURE 2. Long-term results of attempted catheter ablation in 127 patients. Control of arrhythmia was deemed excellent in 90 patients (71%) in whom chronic complete AV block was induced and in eight (6.5%) in whom arrhythmia control was achieved despite resumption of AV conduction. In 16 patients (31%) AV conduction returned but the arrhythmia responded to previously failed drug trials and the procedure was deemed totally ineffective in 13 (10%). Five of the latter underwent successful cardiac electrosurgery. Three patients died suddenly (sudden death) 6 weeks to 5 months after the procedure.](http://circ.ahajournals.org/doi/abs/1027)
Applications proved fatal or resulted in chronic sequelae. Other complications occurred later and for the most part were related to intravascular catheterization and/or insertion of a permanent pacemaker. Ventricular tachycardia was noted in three patients after ablation. In one, the tachycardia appeared to be related to malpositioning of the permanent pacemaker lead and in another, episodes of ventricular tachycardia were suspected but not proven before the ablation.

Proper precautions should be taken both during and after the ablative procedure. The procedure itself should be done by physicians experienced in performing invasive electrophysiologic procedures. It should be appreciated that not all electrode catheters are suitable for ablative procedures. In the present study, the vast majority of catheters used were of a type found to be suitable on the basis of prior animal studies or testing in vitro. In addition, the operators should be prepared to manage serious cardiac arrhythmias as well as the cardiac tamponade. In at least one center, the procedure is performed with a thoracic surgeon in attendance while other centers provide for backup surgical and operating room support during the procedure. Continuous electrocardiographic monitoring in the postablation period is an absolute requirement since there is a small but definite risk of postablation ventricular arrhythmia.

It is difficult to compare the catheter technique with direct surgical ablation of the His bundle since the results of a concurrent surgical series are not available. The registry has attempted to collect data relative to surgical His bundle ablation, but too few have been reported to the registry to allow for meaningful comparison between the two techniques. The available data from previously reported series suggest that the operative mortality for this procedure is between 5% and 10%. Even if all sudden deaths reported in the present series were related to the ablative procedure, the incidence of this complication (2.3%) appears to be less than the reported operative mortality. In addition, the catheter technique has the added advantage of being less costly, involving a shorter hospital stay, and obviating the morbidity associated with thoracotomy and heart-lung bypass.

Limitations. Several important limitations of this study should be emphasized. In a voluntary registry, one cannot completely exclude the possibility of a bias introduced by centers more willing to report positive results. The members of the Executive Committee of the Registry diligently attempted to include all centers at which ablative procedures were used and wide advertisement of the existence of such a registry was disseminated throughout the major cardiology journals both in the United States and in Europe. No effort was made to include or exclude centers on the basis of known results. In addition, at the time the registry was initiated, relatively small numbers of ablative procedures were performed and participating centers were required to update results on a 6-monthly basis. In addition, our results are very similar to those of a recent report summarizing the English experience with the ablative technique. Their data are not part of our registry.

The follow-up period was inadequate to fully assess maintenance of chronic complete AV block. In most patients in whom the procedure failed, AV conduction returned within hours or several days after ablation. Late return of AV conduction occurred 6 and 8 months after ablation in two patients, and hence a longer follow-up period is clearly required to assess long-term maintenance of complete AV block. The reason(s) for success (or failure) of the ablative procedure could not be clearly discerned from the available data. The results were not related to the type of catheter or electrode used since the vast majority of both successful and unsuccessful attempts involved the same type of catheter and electrode configuration. Similarly, the discrepancy could not be explained on the basis of total energy used. In fact, cumulative energy was higher in the unsuccessful attempts (834 ± 562 J) compared with the successful ones (512 ± 371 J). This occurred because unsuccessful attempts were often followed by repeat efforts that were also unsuccessful. Others have emphasized the importance of the size of both the atrial and His bundle deflections before ablation. These data were not available for analysis in the present series. Finally, the causes of the most serious potential complication, namely sudden death, remain undefined. The three sudden deaths appeared to be unrelated to pacemaker failure. In one patient who died suddenly AV conduction resumed, and in two others normal pacemaker function was documented. It is unclear whether the procedure itself resulted in damage to the ventricular summit, which served as a nidus for development of sinus ventricular arrhythmias. Alternatively, each of the patients who died suddenly had organic heart disease. Two, for example, had dilated cardiomyopathy, an entity which in itself is associated with sudden death. Detailed histologic evaluations of these hearts are in progress.

The catheter technique for AV junctional ablation represents an important innovation in the management of patients with drug-refractory supraventricular tachycardia. The most important contribution relates
to the finding that 90% of these patients may be treated without resorting to surgical interruption of the His bundle. The available data suggest that unsuccessful attempts at AV junctional ablation by catheter do not preclude subsequent successful surgical intervention. The data suggest that use of 80 J or less is ineffective for production of chronic complete AV block. The success of the procedure appears to be more related to technical ability in (or anatomic configuration allowing) maneuvering the catheter in close proximity to the AV junction rather than a fixed amount of delivered electrical energy. The known complications of the catheter technique together with pacemaker dependency and possible risk of sudden death mandate that this procedure be used only as a last resort for control of supraventricular arrhythmias. Of interest is the finding of control of arrhythmias in 20% of patients (with or without antiarrhythmic drugs) in whom AV conduction returned. Future efforts should be directed toward the development of techniques that produce less damage to the conduction system so that arrhythmia control is achieved without having to resort to complete pacemaker dependency. In addition, these techniques should be designed to eliminate damage to surrounding myocardium and thus hopefully obviate the problem of the ventricular arrhythmias that have been associated with this technique.

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