Preservation of Atrioventricular Nodal Conduction During Radiofrequency Current Catheter Ablation of Midseptal Accessory Pathways

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Background. Septal accessory atrioventricular (AV) pathways may be located in close vicinity of the His bundle–AV nodal conduction system. Attempts at surgical or electrical interruption of these pathways may therefore result in impairment of normal AV conduction. This study focuses on a subset of septal pathways with an atrial insertion located inside the triangle of Koch. In this study, they were called “midseptal.”

Methods and Results. Six patients with a midseptal accessory pathway (mean±SD age, 40±12 years; five with Wolff-Parkinson-White syndrome and one with a concealed accessory pathway) underwent attempts at ablation of their pathway using 500-kHz radiofrequency current applied to the atrial insertion of the accessory connection. Guided by the recording of accessory pathway activation potentials, the ablation catheter was positioned in all patients in an area bounded anteriorly by the tip electrode of the His bundle catheter and posteriorly by the coronary sinus ostium. All pathways were successfully ablated without the induction of complete heart block. First-degree AV conduction block occurred in one patient in whom a concealed accessory connection was located closer to the AV node than to the coronary sinus ostium.

Conclusions. Radiofrequency current catheter ablation may be used effectively for midseptal accessory pathways and should be preferred in experienced centers as a safe alternative to surgical therapy. (Circulation 1992;86:1743–1752)

Key Words • catheters • ablation • radiofrequency • Wolff-Parkinson-White syndrome • accessory pathways • supraventricular tachycardia

Accessory atrioventricular (AV) connections may be located anywhere along the left and right free walls of the heart or within the septum, except the mitral annular area between the left and right fibrous trigones. Precise anatomic identification of accessory pathway location is a prerequisite for successful ablative therapy, whether surgical1,2 or electrical.3–5 Although surgery allows detailed intraoperative mapping under visual control and under consideration of anatomic structures adjacent to the accessory AV connection, catheter ablation techniques rely exclusively on the analysis of endocardial electrogram recordings obtained during accessory pathway conduction.

The septal region is a complex anatomic entity that contains major parts of the specific conduction system. Although surgical ablation of septal pathways in specialized centers is associated with a very low failure rate, sometimes induction of complete heart block cannot be avoided.1,2,6,7 This has been particularly true for “intermediate” septal accessory pathways. The term was introduced in 1986 by Gallagher et al8,9 to define accessory AV connections in patients whose surface ECG suggested an anteroseptal location of a pathway confined to the posteroseptal space.

A recent study showed that anteroseptal accessory AV pathways can be interrupted, without impairment of His bundle–AV nodal conduction, by applying radiofrequency current from a right atrial catheter position.10 The present report describes catheter ablation of AV bypass tracts located in the septum between the tip of the His bundle catheter and the coronary sinus ostium. The location of these pathways was called “midseptal.”11

Methods

Patients

The patient cohort presented in this report consisted of two women and four men with a mean±SD age of 40±12 years. All were free of organic heart disease. Five patients had Wolff-Parkinson-White syndrome, and one had a concealed accessory pathway. In one patient, the accessory pathway conducted intermittently in anterograde but permanently in retrograde direction (intermittent Wolff-Parkinson-White syndrome). Another patient was found to have additional anterogradely conducting pathways at right anteroseptal and left lateral locations, respectively.

Symptoms included frequent and/or disabling palpitations in all patients, associated with dizziness in one. The duration of symptoms ranged from 1 to 15 years. The last patient enrolled in the study had recently
experienced an episode of syncope. The clinically documented arrhythmias were orthodromic AV reentrant tachycardia in four patients and atrial fibrillation in the other two. Medical therapy had failed in five patients; one patient had not received antiarrhythmic agents.

The six patients included in this study were among 215 consecutive patients who underwent attempts at catheter ablation of accessory pathways using radiofrequency current at our institution between May 1987 and December 1991.

**Electrophysiological Procedure**

All patients were informed about the investigational nature of the catheter ablation procedure and gave their written consent. The protocol had been approved by the Ethics Committee at the University of Hamburg. For stimulation purposes, standard production quadripolar 6F catheters (USCI, Billerica, Mass.) were advanced via the femoral veins to the high right atrium and the right ventricular apex. A decapolar 6F catheter (USCI, 2-mm interelectrode distance) introduced from the right femoral vein was placed across the tricuspid valve to record His bundle potentials. A 6F catheter with three groups of four circumferential electrodes arranged in an orthogonal configuration (“Jackman” catheter; Boston Scientific International, Watertown, Mass.) was positioned from the left subclavian vein into the coronary sinus for coronary sinus mapping. For mapping of the midseptal endocardial aspect of the tricuspid annulus and eventual application of radiofrequency energy, a 7F quadripolar catheter with a 5-mm interelectrode distance and a deflectable tip electrode 4 mm long (Boston Scientific International or OSCOR Medical Corp., Palm Harbor, Fla.) was used. This catheter was introduced from the right femoral vein and positioned against the tricuspid annulus in search of sites of earliest retrograde atrial activation and earliest anterograde ventricular activation and for accessory pathway activation potentials. Mapping with the ablation catheter was performed during sinus rhythm or atrial pacing and during orthodromic tachycardia (or right ventricular pacing when retrograde conduction across the AV node was excluded). Tachycardia was not systematically induced in all patients with overt accessory pathways.

**Analysis of Electrograms**

Six surface ECG leads and at least five endocardial leads, filtered at 50–500 Hz, were simultaneously recorded on a 16-channel recorder (Mingograph, Siemens AG, Erlangen, FRG) at paper speeds of 100 or 200 mm/sec. From these recordings, determined parameters were the shortest coupling intervals conducted 1:1 antegrade and/or retrograe across the accessory pathway and, whenever possible, across the AV node; the atrium-His (AH) interval; and, after ablation, the His-ventricle (HV) interval. Local intervals recorded during sinus rhythm from the distal electrode pair of the ablation catheter and measured onset to onset were atrium–accessory pathway (A-AP), accessory pathway–ventricle (AP-V), and accessory pathway–onset of delta wave in the surface electrogram (AP-Δ). Correspondingly, V-AP and AP-A were measured during orthodromic tachycardia in the patient with a concealed pathway. The peak-to-peak amplitudes of local atrial and ventricular deflections were measured to determine the atrial/ventricular deflection amplitude ratio.

During the procedure, patients were sedated, if necessary, with diazepam (5–15 mg) or anesthetized with fentanyl (0.1–0.5 mg). After catheter positioning, a bolus of 100 units/kg heparin was given intravenously, followed by a second injection of 5,000 units after 4 hours.

**Definition and Localization of a Midseptal Accessory Pathway**

Following the nomenclature of Jackman et al., a midseptal location of the accessory pathway was assumed if an accessory pathway potential was recorded through the distal electrode pair of the mapping/ablation catheter from an area bounded anteriorly by the tip electrode of the His bundle catheter and posteriorly by the coronary sinus ostium as marked by the vertex of curvature in the coronary sinus mapping catheter (Figure 1). In our laboratory, this anatomic definition differentiates a midseptal from an anteroseptal accessory pathway. Anteroseptal pathways are located anterior to the bundle of His and require, by definition, the recording of an accessory pathway potential from both the His bundle and the mapping/ablation catheter, along with a distinct His bundle potential in the former but no or just a tiny His bundle potential in the latter catheter lead. Catheter positioning was performed and recorded in the 30° right and left anterior oblique fluoroscopic views. These later were used for a retrospective estimation of the distances between the ablation catheter and the His bundle and coronary sinus catheters, respectively.

**Catheter Ablation**

Radiofrequency current was applied in a unipolar fashion between the tip electrode of the mapping/ablation catheter and a patch electrode on the patient’s back at sites where large atrial and ventricular potentials were recorded (reflecting a catheter position directly at the tricuspid annulus) in conjunction with an accessory pathway potential (Figures 2 and 3). Current was delivered in the four patients with consistent man-
manifest Wolff-Parkinson-White syndrome during sinus rhythm (Figure 4) and in the patient with intermittent Wolff-Parkinson-White syndrome and the patient with a concealed accessory pathway during orthodromic AV tachycardia (termination of the tachycardia due to loss of retrograde atrial activation would indicate conduction block in the accessory pathway [Figure 5]). After successful ablation of an accessory pathway, one additional "safety" application was given after 1 minute to the same site to minimize the possibility of a late recurrence of accessory pathway conduction.

An electrophysiological evaluation was performed 30–60 minutes after successful accessory pathway ablation. It consisted of right atrial and ventricular stimulation using the extrastimulus technique as well as incremental pacing to exclude the presence of another accessory pathway and to determine the postablation conduction properties of the AV node–His bundle system.

An ablation attempt was considered successful if, at the end of the procedure, both anterograde and retrograde accessory pathway conduction had disappeared or if retrograde conduction through the concealed pathway was no longer present.

Devices
Programmed electrical stimulation with stimuli of 0.5-msec duration at twice-diastolic threshold was performed using the ERA-S-HIS stimulator (Biotronik GmbH, Berlin, FRG). A generator supplying unmodulated 500-kHz alternating current (HAT 200; OSCOR Medical Corp.) was used for ablation in all patients. With this generator, relevant data of radiofrequency current delivery (e.g., power, duration, cumulative energy) are stored on a personal computer system, which, however, does not provide for calculation of voltage, current, or impedance. Current was delivered for 20–30 seconds. Because of unstable wall contact of the ablation catheter, 60-second pulses were delivered only in the first patient.

Follow-up
After the ablation session, all patients were transferred to the regular patient ward. A two-dimensional echocardiogram was performed each day, surface ECGs were recorded twice daily, and the creatine kinase value was determined every 6 hours for the first 2 days. All patients were discharged within 2–5 days on a daily dose of 300 mg acetylsalicylic acid to be maintained over 3 months for thrombus prophylaxis.12

Patients were then seen in the outpatient clinic after 1 and 3 months and every 6 months thereafter. At each visit, the patient’s clinical course was assessed, a physical examination was performed, and a surface ECG as well as a two-dimensional echocardiogram were recorded.
Statistical Analysis

Data are presented as mean±1 SD, where appropriate. In cases of an asymmetrical distribution of measured parameters, the median value is given instead of the mean.

Results

Surface ECG

Concordant surface ECG features were found in the five patients with anterogradely conducting pathways (Table 1). The delta wave polarity was uniformly positive in leads I, II, aVL, and V_2-V_6; predominantly negative in leads III and aVF; and either flat (isoelectric) or negative in leads aVR and V_1. Figure 6 gives a representative example.

General Ablation Data

Seven ablation sessions were performed in the six patients and resulted in permanent abolition of accessory pathway conduction in all of them (Table 2). This was achieved in a single ablation procedure, except for patient 3, in whom conduction across the midseptal pathway recurred 2 hours after conclusion of the initial session, necessitating a repeat session the next day. Mean radiofrequency power (into 250 Ω) was 26.4±4.0 W per application delivered for 24.9±5.7 seconds. The median number of radiofrequency pulses applied to an accessory pathway per session was six (range, 1–30). Sessions lasted for a mean of 3.7±1.6 hours, and radiation exposure time for catheter positioning averaged 48.9±28.6 minutes.

Catheter Positions and Data Related to Accessory Pathway Potentials

For successful attempts at ablation, the distances of the tip electrode of the ablation catheter relative to the tip electrode of the His bundle catheter and the coronary sinus mapping catheter are listed in Table 3 for the 30° right and left anterior oblique fluoroscopic views. They represent in all patients a position of the ablation catheter posterior to the bundle of His but anterior to the ostium of the coronary sinus (Figure 7). Accessory pathway potentials were recorded in all patients. Of note is that in three patients, multiple accessory pathway potentials were found. Table 3 summarizes, for the ablation catheter positioned at the site of the eventually successful pathway interruption, the conduction intervals related to an accessory pathway potential as well as the amplitude ratio of atrial and ventricular potentials. During anterograde conduction, the accessory pathway potential preceded the local ventricular potential and the onset of the delta wave by 17±8 and 21±11 msec, respectively. The atrial/ventricular deflection amplitude ratio ranged from 0.1 to 14.3, with a median of 2.2.

Effect on AV Conduction

Pertinent electrophysiological data are summarized in Table 4. Complete heart block was not induced in any
FIGURE 4. Recording of application of radiofrequency current (RFC on) during sinus rhythm to the accessory pathway in patient 5. Note the almost immediate loss of preexcitation, reflected in the disappearance (fat arrow) of the delta waves (Δ) present in the first four beats.

patient. Impairment of AV conduction after radiofrequency current application to the midseptal accessory pathway was observed only in patient 4, in whom the pathway had concealed conduction properties; intranodal conduction time had increased from 80 to 140 msec (first-degree AV conduction block). It is of note that in this patient the tip electrode of the ablation catheter was farther from the coronary sinus ostium than was the case in the other patients (Figure 8), suggesting a position of the ablative electrode close to the AV node. There were no acute or late complications related to the ablation procedure.

Associated Accessory Pathways

The associated accessory pathways present in patient 3 were successfully interrupted by radiofrequency current application in the initial ablation session.

Follow-up

During a follow-up period of 16.2±2.9 months (range, 12.1–19.8 months), all patients were without antiarhythmic medication and free of arrhythmia-related symptoms. Echocardiograms and ECGs were normal.

FIGURE 5. Recording of application of radiofrequency current (RFC on) during orthodromic tachycardia to the concealed accessory pathway in patient 5. Tachycardia persists for approximately 4 seconds before it is terminated by loss of accessory pathway conduction, indicated by the disappearance (arrow) of retrograde P waves. A short period of ventricular ectopy sets in and gives way to junctional ectopy and fusion beats, probably caused by injury to the atrioventricular node. This application of radiofrequency current resulted in first-degree atrioventricular conduction block.
TABLE 1. Surface ECG Data

<table>
<thead>
<tr>
<th>Patient</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>aVR</th>
<th>aVL</th>
<th>aVF</th>
<th>V1</th>
<th>V2-V6</th>
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<td>+</td>
<td>+</td>
<td>±</td>
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<td>?</td>
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<td>+</td>
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<td>+</td>
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<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
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</table>

Δ, Delta wave; +, positive; −, negative; ±, isoelectric; ?, not available.

Discussion

This report describes successful catheter ablation using radiofrequency current in patients with a midseptally located accessory pathway. These pathways were defined by a position of the ablation catheter midway between the catheter recording His bundle activation and the ostium of the coronary sinus as marked by the coronary sinus mapping catheter.

In 1986, Gallagher et al. introduced the term "intermediate septal" for an accessory pathway characterized by an atrial insertion corresponding to a posteroseptal pathway and a ventricular insertion corresponding to an anteroseptal pathway. In their report as well as in a recent report by Epstein et al., attempts at surgical interruption of these pathways were found to be associated with either a significant risk of failure or induction of complete heart block.

Anatomic Considerations

Midseptal accessory pathways, as defined in this study, insert into the anatomic area known as the triangle of Koch, which is part of the right atrial side of the pyramidal posteroseptal space. The triangle of Koch is bordered superiorly by the tendon of Todaro and inferiorly by the annular extent of the septal tricuspid valve leaflet; it contains the ostium of the coronary sinus in its posterior part. It also encompasses, at its anterior tip where the tendon of Todaro merges with the central fibrous body, the AV node. The bundle of His penetrates the AV junction farther anteriorly through the central fibrous body. Anatomically, midseptal accessory pathways might thus be classified as posteroseptal because their ventricular end inserts into the central portion of the ventricular septum and their atrial end inserts into the posteromedial wall of the right atrium at a variable distance from the AV node. However, use of the term "midseptal" appears justified for three reasons: these pathways exhibit ECG features distinguishing them from "true" posteroseptal pathways, which insert into the posterior ventricular septum; their fluoroscopic localization between His bundle and coronary sinus ostium clearly differs from that of anteroseptal as well as posteroseptal pathways; and they require a unique approach to catheter ablation.

With a right atrial approach, radiofrequency current catheter ablation of anteroseptal accessory pathways, that is, of pathways located in close vicinity of, but anterior to, the bundle of His, has recently been shown to be highly effective and safe without producing third-degree AV conduction block. This approach was associated with a risk of producing right bundle branch block yet has a lower incidence than was observed using a ventricular approach.

Catheter Ablation of Midseptal Pathways

In this study, positioning of the ablation catheter at the midseptal region was guided by the direct recording of accessory pathway activation potentials. These potentials were obtained in all patients. Thus, the catheter was positioned at the site of the atrial insertion of the accessory pathway in all patients. Of note is that in three patients, multiple accessory pathway potentials could be recorded through the same catheter electrode,
TABLE 2. Patient Characteristics and Ablation Session Data

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (years)</th>
<th>Sex</th>
<th>WPW</th>
<th>Power (W) (mean)</th>
<th>Duration (seconds) (mean)</th>
<th>Energy (J) Cumulative Mean</th>
<th>Session duration (hours)</th>
<th>Rad exp (minutes)</th>
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<td>Male</td>
<td>Overt</td>
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<td>29.6</td>
<td>34.6</td>
<td>30,958 1,032</td>
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<td>54</td>
<td>Male</td>
<td>Overt</td>
<td>10</td>
<td>28.0</td>
<td>19.5</td>
<td>5,577 558</td>
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<tr>
<td>3*</td>
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<td>Overt</td>
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<td>21.7</td>
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<tr>
<td>6</td>
<td>41</td>
<td>Female</td>
<td>Overt, intermittent</td>
<td>16</td>
<td>19.7</td>
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<td>6,420 401</td>
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</table>

WPW, conduction characteristics of accessory pathway; Rad exp, radiation exposure time.
*Associated left lateral and right anteroseptal overt accessory pathways.

suggesting a pathway diverging into multiple strands. Another plausible explanation may be the oblique course of midseptal pathways on the right atrial septal surface, which makes them more parallel with the ablation catheter. Such a high incidence of multiple accessory pathway potentials has not been reported for other accessory pathway sites.10,17 On average, the accessory pathway potential preceded the onset of the delta wave by 21 msec. The local ventricular potential preceded the onset of the delta wave in two patients and coincided with it in three.

At sites where accessory pathway potentials were recorded, fluoroscopy revealed that the ablation catheter was positioned in the posterior aspect of the triangle of Koch, that is, closer to the coronary sinus ostium than to the AV node, in four of the five patients with manifest preexcitation. The corresponding accessory pathways gave rise to a delta wave polarity predominantly negative in leads III and aVF but positive in leads I, II, and aVL.18 In the series of Gallagher et al,8 patients also had a positive delta wave polarity in the latter three leads but isoelectric, rather than negative, polarity in leads III and aVF. Patient 2 in our series also presented with such a delta wave pattern. It indicates a midseptal accessory pathway located closer to the AV node—thus, more anterior than the majority of pathways encountered in our series. The delta wave pattern described by Epstein et al9 for their “type 1” intermediate septal pathways indicates that these pathways also correspond to our midseptal accessory pathways. However, their “type 2” intermediate accessory pathway (positive delta waves in leads II, III, and aVF) corresponds to our definition of an anteroseptal accessory pathway.10

In contrast to the reported experience with surgical ablation of intermediate septal pathways,8,9 permanent interruption of accessory pathway conduction was achieved in the present study, as well as in a previous study on anteroseptal pathways,10 with preservation of AV nodal conduction in all patients. A repeat session was required only for the patient with multiple pathways. In this patient, the initial session was concluded when all three pathways were thought to have been successfully ablated. However, accessory pathway conduction across the midseptal pathway recurred after 2 hours, necessitating a repeat session the next day. This was completed successfully, using a single catheter introduced from the right femoral vein. As for pathways located right posterocephally and posteriorly,3,10 the femoral approach was always used in this study, with the catheter placed in the majority of patients so that the

TABLE 3. Conduction Intervals Related to an Accessory Pathway Potential and Catheter Distances

<table>
<thead>
<tr>
<th>Patient</th>
<th>A-AP (msec)</th>
<th>AP-V (msec)</th>
<th>AP-A (msec)</th>
<th>V-AP (msec)</th>
<th>AP-A (msec)</th>
<th>A/V</th>
<th>d(HIS) (mm)</th>
<th>d(CS) (mm)</th>
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<td>Mean</td>
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<td>2.9</td>
<td>5.0</td>
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A, atrium; AP, accessory pathway; Δ, onset of delta wave; A/V, atrial/ventricular deflection amplitude ratio; V, ventricle; RAO, 30° right anterior oblique view; d, distance to the ablation catheter; HIS, bundle of His; LAO, 30° left anterior oblique view; CS, coronary sinus ostium.
*Two AP potentials recorded.
amplitude ratio of local atrial and ventricular potentials well exceeded unity.

**Effect on AV Conduction**

Prolongation of anterograde AV nodal conduction time after radiofrequency current application to the midseptal pathway was observed only in the patient with a concealed accessory pathway. However, this impairment of AV nodal conduction was not associated with an apparent change of 1:1 AV conduction. Because a single 30-second radiofrequency pulse sufficed for ablation of the accessory pathway in this patient, a rather close anatomic relation of the pathway to the AV node can be assumed. This was confirmed by fluoroscopy. To avoid first-degree or even higher degree AV conduction block in a situation where an accessory pathway potential is recorded from a midseptal site nearer to the AV node than to the coronary sinus ostium, it might be advisable to start the ablation attempt with low energies (10–15 W) and increase ablative energy only if no effect is achieved.

**Methodology**

Regardless of accessory pathway location, there remains uncertainty as to why in one patient 30 radiofrequency current pulses were necessary for permanent abolition of accessory conduction, whereas another required only one application of current. Several factors may account for “failed” current applications. The catheter position at the tricuspid annulus may not be stable or it may not be sufficiently precise (the influence of the latter factor can be minimized if catheter positioning is guided by the recording of an accessory pathway potential rather than by activation sequences). Furthermore, the anatomy of the region containing the accessory pathway or the pathway itself may require deeper and wider lesions to destroy all pathway fibers, and, at present, this can be achieved only with multiple applications of radiofrequency current.

**Study Limitations**

The number of patients included in this study represents 3% of all our patients treated with radiofrequency current for accessory pathway mediated tachyarrhythmias. This number is small, but data from other investigators suggest that the general incidence of these pathways is low. Furthermore, a 16-month follow-up may be too short to judge definitively the efficacy and

<table>
<thead>
<tr>
<th>TABLE 4. Basic Electrophysiological Data</th>
<th>Preablation (msec)</th>
<th>Postablation (msec)</th>
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<tbody>
<tr>
<td>CI 1:1 via AP</td>
<td>CI 1:1 via AVN</td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>Anterograde</td>
<td>Retrograde</td>
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<tr>
<td>1</td>
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<td>420</td>
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<td>2</td>
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<td>250</td>
</tr>
<tr>
<td>6</td>
<td>640</td>
<td>620</td>
</tr>
</tbody>
</table>

CI, coupling interval; AP, accessory pathway; AVN, ativoventricular node; SR, sinus rhythm; TCL, tachycardia cycle length; VA diss, ventriculoatrial dissociation.

Tachycardia was not induced in patients 2, 3, and 6.
effects of radiofrequency current application to a midseptal site. This is particularly true for the long-term effect on AV nodal conduction. However, in our laboratory, we have not seen the impairment of AV nodal conduction occurring more than 1 week after an electrical intervention, even when radiofrequency current had been directed intentionally toward the AV node to modify (without interrupting) AV nodal conduction in patients with atrial fibrillation or flutter.20

Conclusions

Catheter ablation of midseptal accessory pathways using radiofrequency current is effective and appears to be safe. In contrast to surgical techniques, complete heart block was never induced. Impairment of AV nodal conduction was observed in one of six patients. Long-term data obtained from larger series of patients will be needed for further evidence that this approach is potentially the treatment of first choice for patients suffering from tachyarrhythmias mediated by a midseptal accessory pathway. However, in experienced centers, it should definitively be used before surgical intervention is contemplated.

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