Catheter-Induced Mechanical Conduction Block of Right-Sided Accessory Fibers With Mahaim-Type Preexcitation to Guide Radiofrequency Ablation

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Background Accessory pathways originating at the tricuspid annulus that exhibit decremental antegrade conduction properties (Mahaim-type preexcitation) are amenable to radiofrequency (RF) current catheter ablation. However, a reliable and reproducible strategy for mapping and ablation of these fibers is lacking.

Methods and Results Eleven patients with preexcited atrioventricular tachycardia involving a decrementally conducting antegrade accessory pathway underwent complete electrophysiological evaluation and subsequent attempts at RF catheter ablation. Mechanical conduction block at the subannular level of the atrial input to the accessory fiber was induced by catheter manipulation in 8 patients, in 2 of them during atrial fibrillation. RF current was delivered, after resumption of preexcitation, to the site of mechanical block during atrial pacing (n=6) or atrial fibrillation (n=2) and eliminated the accessory pathway in all 8 patients. In another patient, mechanical block was not observed, but ablation of the atrial accessory fiber insertion was achieved at the subannular level during atrioventricular tachycardia. The anatomic site of ablation along the tricuspid annulus was anterolateral (n=1), lateral (n=3), or posterolateral (n=5). Failures were encountered in the first patient of the series in whom ablation attempts were directed at the ventricular insertion of the accessory fiber and in a patient in whom ablation of the atrial insertion was attempted at the suprannular level. Recurrence of preexcitation within 12 hours was observed in 5 of 6 patients in whom ablation had been achieved during atrial pacing. Eventually successful repeat sessions were performed the following day using a simplified ablation approach. Thus, a median of 5 RF pulses (range, 1 to 26) per accessory fiber eliminated conduction in 9 (82%) of the 11 patients in 1.9±0.9 sessions. During a follow-up of 9.5±2.3 months, preexcitation recurred in 1 patient.

Conclusions The atrial origin of accessory connections with Mahaim-type preexcitation is apparently confined to the anterolateral-posterolateral region of the tricuspid annulus. Mechanical conduction block in the atrial input to the accessory fiber induced at the subannular level by catheter manipulation provides an optimal marker to locate the ablation site, even during atrial fibrillation. To expose early recurrence of antegrade accessory pathway conduction, intermittent atrial pacing in the 12 hours after ablation is advisable; in cases of recurrence, a repeat procedure can readily be performed using just the ablation catheter advanced to the target site at the tricuspid annulus. (Circulation. 1994;90:282-290.)

Key Words • radiofrequency • ablation • conduction • Mahaim fibers

The anatomic and electrophysiological concepts of accessory fibers exhibiting decremental antegrade conduction properties (Mahaim-type preexcitation) have required considerable reevaluation since their original description in 1938. The presence of decremental antegrade conduction and ventricular preexcitation, associated with the anatomic demonstration of extensions of the atrioventricular conduction system from within the central fibrous body to the right ventricle, was initially misleading because attention was focused on the atrioventricular node. Recently, electrophysiological and surgical evidence has been provided for the existence of accessory fibers with slow and decremental antegrade conduction located along the tricuspid annulus, remote from the atrioventricular node. The atrial origin of these accessory pathways has been shown to be a safe target for radiofrequency (RF) current catheter ablation. However, because of their right-sided location and the absence of retrograde conduction, these accessory pathways necessitate complex and time-consuming catheter techniques for ablation. An easy, reliable, and reproducible strategy for mapping and ablation in patients with right-sided decrementally conducting antegrade accessory pathways is still lacking. The present study was designed with the objective of devising such a strategy and to provide further insights into the anatomy and electrophysiology of these fibers.

See p 636

Methods

Patients

Between May 1987 and March 1993, 488 consecutive patients underwent RF current catheter ablation of an accessory pathway at our institution. Of these, 11 (8 men, 3 women; 30±9 years old) had reciprocating supraventricular tachycardias on the basis of an accessory atrioventricular connection capable of consistent decremental antegrade conduction only.
All 11 patients had experienced symptomatic spontaneous tachyarrhythmias. Symptoms included disabling palpitations, nausea, dizziness, and presyncope; syncope was reported in 2 patients. The duration of symptoms ranged from 4 to almost 31 years. Before ablative therapy, patients had undergone drug trials with a median of three antiarrhythmic agents (range, one to five). One patient had underlying mitral insufficiency, and 1 had previously undergone RF current ablation of a right posteroseptal accessory pathway. Minimal preexcitation on the surface ECG during sinus rhythm was recorded in 2 patients; the QRS pattern during antidromic tachycardia exhibited a left bundle branch block morphology in all cases, with a left axis deviation in 8.

**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. The patients were studied after all cardioactive drugs had been discontinued for at least five half-life times. The mapping procedure has been described in detail elsewhere. In brief, two standard production 6F quadripolar catheters (5-mm interelectrode distance; USCI), introduced via the femoral vein, were advanced under fluoroscopic guidance to the right atrium and the right ventricular apex, respectively. A 6F decapolar catheter (2-mm interelectrode distance; USCI) was placed at the bundle of His. A 6F catheter, with three groups of four circumferential electrodes arranged in an orthogonal configuration (“Jackman”-type catheter; Boston Scientific International) was positioned via the left subclavian vein into the coronary sinus for coronary sinus mapping. For mapping of the tricuspid annulus and right ventricle and eventual ablation of the accessory fiber, a steerable 7F quadripolar catheter with 2-mm interelectrode distance and a tip electrode of 4-mm length (Boston Scientific or OSCOR Medical Corp) introduced by way of the femoral vein was used (Fig 1). The atrioventricular annuli were mapped during atrioventricular tachycardia and during sinus rhythm or atrial pacing.

Programmed electric stimulation with stimuli of 0.5-millisecond duration at twice diastolic threshold was performed with an ERA-S-HIS stimulator (Biotronik GmbH). Six surface ECG leads and at least five endocardial leads were simultaneously recorded on a 16-channel recorder (Mingograph, Siemens AG) at a paper speed of 100 mm/s. Local electrograms were filtered at 50 to 500 Hz and amplified at a gain of 20 mm/mV.

**Accessory Fiber as a Critical Component of the Tachycardia Circuit**

The presence and participation of the accessory connection as a critical component in the antidromic reciprocating tachycardia circuit were defined according to criteria suggested by Gallagher et al. With incremental atrial pacing and progressive prematurity of atrial extrastimuli, the QRS complex became increasingly preexcited as the onset of the His bundle deflection was delayed to succeed the onset of the QRS complex and the atrioventricular interval concurrently lengthened. During maximal preexcitation, the QRS complexes assumed a left bundle branch block morphology identical to the configuration during tachycardia. Earliest retrograde atrial activation was recorded at the His bundle during both ventricular pacing and antidromic tachycardia. In all patients, the clinical tachycardia (cycle length, 319±31 milliseconds) was inducible by atrial or ventricular extrastimuli or by rapid atrial or ventricular pacing.

The macro reentrant tachycardia wave front was considered to penetrate the accessory connection in the antegrade direction and the specific conduction system in the retrograde direction on the grounds of the following findings: (1) initiation, resetting, and/or termination of antidromic tachycardia by a ventricular extrastimulus was consistent with the right ventricle as a critical component of the reentrant circuit; (2) ventricular extrastimuli failed to dissociate ventricular activity from tachycardia; (3) timed ventricular extrastimuli (given slightly before the His bundle deflection) advanced retrograde atrial activation; (4) despite variable coupling intervals of triggering atrial or ventricular extrastimuli, either a constant interval linked the first preexcited QRS complex of tachycardia with the next atrial retrograde activation potential or no fusion (or transition with narrow QRS complexes) was observed during reciprocating tachycardia; (5) no fusion was observed during reciprocating tachycardia in response to the introduction of atrial or ventricular extrastimuli; and (6) identity of the V-H interval during antidromic tachycardia and maximally preexcited beats.

**Criteria Distinguishing Atrial From Nodal Origin of the Accessory Fiber**

During electrophysiological evaluation, the atrial origin was distinguished from a nodal (or fascicular) origin of the acces-
sory fiber whenever one or more of the following criteria were met: (1) late right atrial extrastimuli (delivered as late as 40 milliseconds after onset of the low right atrial septal electrogram) advanced ventricular activation during preexcited tachycardia without affecting atrial activation at the low right atrium; (2) the presence of tachycardia entrainment with atrial fusion during right atrial pacing was found; and (3) ventricular preexitation was more readily exposed by pacing from the right atrium than from the coronary sinus.

Localization of the Atrial Insertion of the Accessory Fiber

During mapping at the tricuspid annulus, criteria for the precise localization of the atrial insertion of the accessory atrioventricular connection were (1) the occurrence of catheter-induced mechanical block of antegrade conduction over the accessory fiber during atrial pacing at cycle lengths that resulted in constantly preexcited beats; (2) the endocardial or epicardial (via a right coronary artery mapping catheter) recording of an accessory pathway activation potential clearly separated from local atrial and ventricular activation potentials; and (3) the identification of the site along the atrial aspect of the tricuspid annulus where the shortest stimulus-to-QRS interval of maximally preexcited beats was recorded during pacing at a fixed cycle length of 400 milliseconds.

Mechanical Conduction Block in the Accessory Fiber

This phenomenon was initially observed by chance in the first 2 patients in whom mapping of the tricuspid annulus was performed (ie, patients 4 and 6). In all subsequent patients, including 2 who underwent a repeat session (ie, patients 2 and 3), attempts to induce mechanical block were made intentionally by positioning the tip of the mapping catheter along the tricuspid annulus with as much pressure as possible. To this end, the catheter was positioned at the tricuspid annulus in the posterior-to-posterolateral region (as verified in the 30° left anterior oblique view) and curved with a counterclockwise torque. We assumed that the recording through the catheter tip of a large ventricular potential but only a small or no atrial potential was consistent with a catheter position at the subannular level, whereas a ratio of atrial to ventricular amplitude larger than 1 identified a catheter position at the supra-annular level. With both the curve and the counterclockwise torque maintained, the catheter was then slowly advanced toward the anterolateral region along the subannular aspect of the tricuspid annulus. When mechanical conduction block was achieved, the catheter was left in place, and the contact pressure was released by reducing the torque. On resumption of accessory fiber conduction, repeat attempts at inducing mechanical block were made. The described procedure was not performed in patients 1 and 5.

Coronary Artery Mapping

The endocardial recording at the tricuspid annulus of an accessory pathway activation potential may be compromised by catheter instability. Therefore, additional right coronary artery mapping was performed in 6 patients. After full coagulation with intravenous heparin and right coronary angiography via an 8F Judkins catheter, a quadripolar 2F catheter with a 3-mm interelectrode distance was advanced by way of the right coronary artery to the region of the crux of the heart by use of a rapid exchange system and a conventional angioplasty wire. Mapping for an accessory pathway potential was performed while the catheter was slowly withdrawn from the crux to the coronary artery os.

Ablation Technique

Electrocoagulation was attempted with a 500-kHz continuous-wave current generator (HAT 200; OSCOR Medical). RF current was delivered in a unipolar fashion primarily during atrial pacing maintaining maximal preexcitation or during atrioventricular reentrant tachycardia and atrial fibrillation, when present. Surface leads II and III and one to three endocardial leads were recorded at 25 mm/s (Mingograph, Siemens) during current delivery.

In the first 2 patients and in the initial session performed in patient 3, RF energy was delivered to the presumed ventricular insertion of the accessory fiber, at the site of earliest ventricular activation of preexcited beats and possibly in the presence of a local accessory pathway potential clearly distinguishable from a right bundle branch potential. In patient 4, attempts were made to ablate the atrial insertion of the accessory fiber at the supra-annular level. From patient 5 on and in the last three repeat sessions performed in patient 2, attempts were focused on ablatting the atrial input to the accessory fiber at the subannular level, at a site at which mechanical conduction block in the accessory fiber was induced by catheter manipulation.

During the procedure, patients were sedated, if necessary, with diazepam (5 to 15 mg) or were anesthetized with fentanyl (0.1 to 0.5 mg). After catheter positioning, a bolus of heparin 100 U/kg IV was given, followed by a second injection of 5000 U over 4 hours.

After ablation of an accessory fiber, one additional “safety” application was delivered after 1 minute to the same site to minimize the possibility of a late recurrence of accessory fiber conduction.

Anatomic fiber location was classified in the 30° left anterior oblique fluoroscopic view according to the catheter position at the site of a successful pulse delivery.

An electrophysiological evaluation was performed 30 to 60 minutes after accessory fiber 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. Another control atrial stimulation was performed the next day to expose possible early recurrence of accessory conduction. To this end, the right atrial catheter was left in place for the next 24 hours in patients 7 through 11, and atrial pacing was performed every 4 hours.

An ablation attempt was considered successful if, at the end of the procedure, antegrade accessory pathway conduction had disappeared. In case of a recurrence of preexcitation, ablation was reattempted by introducing just the mapping/ablation catheter and advancing it to the tricuspid annulus ("simplified" procedure) (Fig 2).

Statistics

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

Results

Characteristics of the Accessory Fiber

In all patients, the electrophysiological study revealed that the accessory connection had an atrial origin located along the right free wall and that the atria were a critical component of the macro reentrant circuit during tachycardia. The earliest ventricular activation during preexcited beats or antidromic tachycardia was recorded in the vicinity of the right bundle branch in patients 1, 2, and 3. In the other patients, except for patient 5, no attempts were made to precisely determine the ventricular insertion site of the accessory fiber. In all of them, the interval between the onset of the delta wave and the local ventricular electrogram recorded at
## Procedural Data

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Preexc indicates mode of preexcitation during ablation: V, ventricular; AVRT, preexcited atrioventricular reentrant tachycardia; (U), unsuccessful; A, atrial; (S), successful; (R), recurrence; TA-v, subannular level at tricuspid valve; antlat, anterolateral; postlat, posterolateral; TA-a, supra-annular level at tricuspid valve; ant, anterior; lat, lateral; and AFib, atrial fibrillation.

*The number of mechanical conduction blocks is followed in parentheses by the range of the duration of block in seconds.

the subannular level of the tricuspid valve (Δ-V interval) was equal to or exceeded +25 milliseconds. The onset of this local ventricular electrogram always succeeded or coincided with the onset of the ventricular electrogram recorded from the His bundle catheter. In patient 5, the accessory fiber activated the right ventricle immediately below the tricuspid annulus (Δ-V interval = −20 milliseconds).

### Mapping Techniques to Localize the Atrial Insertion of the Accessory Pathway

#### Mechanical Block of Antegrade Accessory Pathway Conduction

A median of two (range, one to seven) transient antegrade conduction blocks were mechanically induced in nine fibers near their atrial origin, either at the supra-annular (3 patients) and/or at the subannular (8 patients) level (Fig 3). No attempts at inducing mechanical block were made in patient 1 because both ablation sessions were directed at the ventricular insertion of the accessory fiber. In patient 5, the anatomy of the accessory fiber allowed easy localization by standard mapping techniques. Reproducibility of mechanical block induction was verified in all other patients with the exception of patient 4, in whom block at the supra-annular level could be induced only once. The anatomic location of mechanically induced conduction block was anterior in 1 patient (supra-annular only), anterolateral in 1 patient, lateral in 3 patients, and posterolateral in 5 patients. The median duration of mechanical block was 19 seconds (range, 7 to 132 seconds).

In 6 patients, a mean of 1.7±0.8 episodes of atrial fibrillation with varying degrees of preexcitation occurred during mapping. In the first 4 patients, sinus rhythm had to be restored by 3±1 DC cardioversions under general anesthesia to allow continued and precise mapping. In patient 10, because of repeated recurrence of atrial fibrillation shortly after cardioversion, mapping was eventually chosen to be performed during atrial fibrillation (mean cycle length, 426±171 milliseconds), and mechanical block of the atrial input to the accessory fiber was induced at the subannular level within 8 minutes (Fig 4). During atrial fibrillation (mean cycle length, 434±103 milliseconds) in patient 11, mapping was continued and no attempts at cardioversion were made; mechanical block at the subannular level of the atrial input to the accessory fiber was achieved within 9.5 minutes.
Accessory Pathway Potential Recording

The recording of an accessory pathway activation potential was aimed for in all patients. Such a potential was recorded at the atrial insertion in 6 patients through the endocardial mapping catheter (Fig 3), and additionally in 2 of 6 patients in whom right coronary artery mapping was performed (Fig 5). In the former 6 patients, the site of recording of the accessory pathway activation potential coincided with the anatomic location of the atrial insertion of the accessory connection as determined by catheter ablation.

In patients 2 and 5, catheter stability allowed continuous accessory pathway potential recording during atrial stimulation to assess the decremental conduction properties of the accessory fiber. In both patients, the atrium-accessory pathway interval prolonged with increasing prematurity of the atrial extrastimulus, whereas no changes were observed in the accessory pathway-ventricle interval, indicative of decremental conduction being confined to the proximal portion of the accessory fiber. During atrial pacing, no spontaneous episodes of conduction block in the accessory fiber were observed.

Stimulus-to-QRS Interval

Pace-mapping along the tricuspid annulus to localize the atrial insertion of the accessory pathway was performed in 6 patients. In 2 patients, the shortest stimulus-to-QRS interval coincided with the anatomic location of the accessory pathway as determined by catheter ablation; in 2 others, the stimulus-to-QRS interval at the ablation site was identical to that recorded from an adjacent region; in one patient it was 15 milliseconds longer than that of an adjacent region. In patient 4, stimulus-to-QRS interval mapping could not be validated because catheter ablation of the accessory fiber was not achieved.

The technique was not performed in patient 1 because only the ventricular insertion of the fiber was assessed; in patient 3 because mechanical block occurred at the very beginning of the mapping procedure and current was subsequently given, and in patients 10 and 11 because of recurrence of atrial fibrillation.

General Ablation Data

See Table. A total of 23 ablation procedures were performed in the 11 patients, and abolition of accessory conduction was eventually achieved in 9 patients. In all 9 patients, the successful ablation attempt was directed at interrupting the atrial input to the accessory fiber at the subannular level. With the exception of patient 5, mechanical block was induced at the site of eventual ablation in these patients. Current was delivered when mechanical block had subsided and accessory conduction resumed. The anatomic location of successfully ablated accessory fibers was anterolateral in 1 patient, lateral in 3 patients, and posterolateral in 5 (Fig 6).

A median of 5 (range, 1 to 26) RF current pulses were applied to the nine successfully divided accessory fibers in 1.9±0.9 sessions per patient. Cumulative energy delivered to the atrial insertions of these accessory fibers ranged from 2557 to 22 035 J, with a median value of 3979 J. The sessions lasted for an average of 7.3±3.2 hours (range, 3.3 to 11.3 hours). The patients' mean radiation exposure time per accessory pathway amounted to 85.5±37.1 minutes (range, 40.6 to 131.4 minutes).

Although mechanical block of the atrial input to the accessory fiber was induced at the supra-annular level in patient 4, ablation at this site could not be achieved.

Patient 5 exhibited decremental antegrade conduction over a right posterolateral atrioventricular accessory connection in which the ventricular insertion was located directly below the tricuspid annulus. Catheter ablation in this patient was guided by accessory pathway potentials recorded from a coronary artery mapping catheter. After ablation, accessory pathway potentials could still be recorded from the epicardial (ie, coronary artery) as well as the endocardial mapping catheter, despite the absence of preexcitation; this indicates that ablation had been achieved at the accessory pathway-ventricle interface.
In the last 2 patients of this study, RF current was delivered during atrial fibrillation, with the catheter left at the site along the tricuspid annulus at which mechanical block had been induced. RF current pulses were applied after accessory pathway conduction had resumed. Three and 9 RF current applications abolished accessory pathway conduction in the 2 patients, respectively.

**Fig 3.** ECGs obtained during pacing of the high right atrium (HRA) at a cycle length of 370 ms in patient 2. Shown are surface ECG leads II and III and three endocardial recordings. Manipulation of the mapping catheter at the anterolateral tricuspid annulus results in loss of preexcitation in the last two beats because of mechanically induced conduction block in the accessory fiber. Note that an accessory pathway potential (AP) is recorded throughout by the mapping catheter (R antlat), indicating interruption of antegrade conduction at the subannular level of the atrial input to the accessory fiber. The A-AP interval remains constant at 50 ms, but the AP-V interval prolongs from 70 to 120 ms after the onset of mechanical conduction block in the accessory pathway. His indicates His bundle.

**Early Recurrence of Conduction Over the Accessory Fiber**

Early recurrence of accessory pathway conduction within 12 hours was exposed by atrial pacing in 5 of the 6 patients in whom the ablation attempt had been directed at the subannular atrial input to the accessory fiber during atrial pacing, necessitating two repeat sessions within 24 hours in 4 patients and a single repeat session in the other. All repeat sessions used the "simplified" procedure. The final repeat session was successful in all 5 patients. Note that accessory fiber conduction did not recur in the 2 patients in whom ablation was performed during atrial fibrillation.

**Fig 4.** Preablation ECGs obtained from patient 10. Manipulation of the mapping catheter at the posterolateral tricuspid annulus during atrial fibrillation results in transient abolition of preexcitation (arrow) because of mechanical conduction block. ECG leads II, III, aVL, and the endocardial recording (R postlat) from the mapping catheter are shown.

**Ablation Attempts Directed at the Ventricular Insertion of the Accessory Fiber**

Two sessions directed at ablating the ventricular accessory pathway insertion in patient 1 were both unsuccessful; RF current in this patient was repeatedly given in the right midseptal region where the shortest A-V interval (~10 milliseconds) was recorded in the presence of a distinct potential preceding the local ventricular potential by 10 milliseconds. Whether this distinct potential originated from fascicular or accessory fiber activation could not be assessed. In patients 2 and 3, RF current applied in the same area, at sites of earliest ventricular activation and in the presence of a
distinct potential preceding the local ventricular potential, resulted in transient accessory pathway conduction block simultaneously with the onset of a transient right bundle branch block. Accessory fiber conduction resumed during the next few hours in both patients.

Follow-up

During a mean follow-up period of 9.5 ± 2.3 months, late recurrence of tachycardia (after 2 weeks) was observed only in patient 3. This patient is currently scheduled for another attempt at catheter ablation of the accessory fiber, as is patient 4. Patient 1 was lost to follow-up. All other patients were without antiarrhythmic drugs and free of arrhythmia-related symptoms.

Discussion

The results of the present study confirm the feasibility and efficacy of RF catheter ablation at the atrial origin of accessory fibers exhibiting Mahaim-type preexcitation. Furthermore, the present data provide a reliable and reproducible strategy for precise localization at the tricuspid annulus of the target site for RF current application.

The incidence of decrementally conducting antegrade accessory fibers among all clinically relevant accessory atrioventricular connections is low; it was 2% in the whole series of patients presented at our institution. However, their incidence among all accessory tracts exhibiting slow and decremental antegrade conduction is apparently high: in the present series, a nodoventricular accessory fiber associated with antidromic tachycardia was not found.

Strategy of Mapping for Identification of the Atrial Insertion

Three mapping techniques were used in this study: the induction by catheter manipulation at the tricuspid annulus of mechanical conduction block in the accessory pathway; the recording of a local accessory pathway activation potential along the right atrioventricular junction; and the analysis of stimulus-to-QRS intervals of maximally preexcited beats during pacing at a fixed rate from the tricuspid annulus.

Transient block of antegrade conduction induced by catheter manipulation at the atrial insertion of the accessory pathway was obtained in 9 of 10 patients; its duration never exceeded 2.2 minutes. This technique proved to be the most reliable for precise mapping of the accessory pathway atrial insertion in all cases, including the 2 patients with preexcited atrial fibrillation. In the 8 patients in whom the induction of mechanical block was attempted at the subannular level, the approach proved to be easily reproducible. After resumption, definitive abolition of accessory pathway conduction was always accomplished by delivering RF current to the site of transient mechanical block. The 1 patient in whom the induction of mechanical block was attempted at the supra-annular level was the first in whom the technique was performed; mechanical block could be achieved once, but delivery of RF current failed to interrupt the accessory fiber. At that time, attempts at inducing mechanical block at the subannular level were not considered.

The recording of a local accessory pathway potential proved to be a useful technique. In this study, the recording site of an accessory pathway potential coincided with the atrial insertion of the accessory pathway in all cases. However, no such potential could be recorded from the eventual ablation site in 3 (33%) of 9 patients. Right coronary artery mapping yielded accessory pathway potential recordings in only 2 of 6 patients. In both patients, accessory pathway potentials were also recorded through the endocardial mapping catheter. Thus, activation potentials of accessory fibers with Mahaim-type preexcitation were more easily recorded from an endocardial catheter position. This finding is consistent with an accessory pathway coursing subendocardially across the atrioventricular junction. Persistence of an accessory pathway potential in the absence of preexcitation, as observed in 1 patient, proves that transient mechanical or permanent block of conduction through these fibers can be induced at a site distal to their atrial insertion.

Stimulus-to-QRS interval mapping appears to be of poor utility. In our experience, it helped to identify the anatomic location of the accessory fiber in only 2 of 6 cases.
in which it was systematically performed. Among its limitations are the difficulty in maintaining a stable catheter position at the tricuspid annulus during pacing at high rates and the incomplete knowledge about the anatomic and functional characteristics of the atrium/accessory pathway interface in these fibers. Such factors may explain the unexpected finding of an identical or even shorter stimulus-to-QRS interval recorded from regions distal to the atrial insertion of the accessory fiber. Furthermore, it is not known whether the optimal site for ablation is located where adequate pacing is obtained.

Ablation During Atrial Fibrillation

To establish stable conditions for localizing the atrial insertion of the accessory pathway, 4 patients in our series required repeat electric cardioversion because of recurrent atrial fibrillation. During mapping in sinus rhythm, mechanical conduction block at the subannular level of the atrial input to the accessory pathway was easily and repeatedly induced by catheter manipulation in all 4 patients. Therefore, in the last 2 patients in whom atrial fibrillation occurred during the ablation procedure, mechanical accessory pathway conduction block in the right posterolateral region of the tricuspid annulus was aimed for; it was induced within 10 minutes of mapping during atrial fibrillation. With the catheter left in place, RF current was delivered as soon as conduction resumed and abolished accessory pathway conduction in both patients.

Optimal Site of Ablation

Ablation at the atrial insertion of decrementally conducting antegrade accessory fibers was always achieved when current was directed at the subannular level of the atrial input to the accessory fiber, with the catheter positioned such that a low ratio of atrial to ventricular amplitude was recorded. Therefore, although other potentially successful sites cannot be excluded, the endocardial breakthrough of the accessory fiber beneath the tricuspid annulus appears to be an optimal site for ablation.

Mechanical Conduction Block

The mechanically induced transient conduction block appears to be a unique phenomenon associated with accessory fibers exhibiting Mahaim-type preexcitation. It was also observed in a recent case report. In our own experience, a comparatively high incidence is not found in "regular" accessory atrioventricular pathways and has likewise not been reported in the literature. Mechanical conduction block appears to be easily inducible in Mahaim-type accessory fibers with a distal extension into the ventricular wall. The ventricular extension of these fibers is apparently electrically insulated, as evidenced in 3 patients by an earliest site of ventricular activation in the vicinity of the right bundle branch. This finding is confirmed by recent studies. The ease with which mechanical block can be induced at the proximal input to these fibers suggests a rather superficial (ie, endocardial) anatomic course of their ventricular extension, at least in the subannular region. The exact site of ventricular activation by way of the accessory fiber was not assessed systematically in this study; it may be anywhere along the right free wall and/or the septum.

Early Recurrence of Preexcitation

After the therapeutic procedure, atrial pacing exposed early recurrence of conduction over the accessory pathway in 5 patients, in 4 of them even after a repeat session. Among the possible reasons accounting for early recurrence are catheter instability at the right atrioventricular annulus and mechanical block during RF current application due to a slight displacement of the catheter. Because mechanical block is a consequence of pressure exerted on the tissues surrounding the accessory pathway, one cannot exclude that RF current delivered at such a site affects the accessory pathway only in part, thus favoring early recurrence. Also, the investigators' learning experience with catheter mapping to induce mechanical accessory pathway block may have contributed to the incidence of early recurrence; this needs to be evaluated in a prospective fashion.

Atrioventricular Fibers With Decremental Antegrade Conduction

Data from this and previous studies* are in agreement with the anatomic presence of dual atrioventricular conduction systems in humans. In addition to the normal connection, an accessory pathway exhibiting decremental antegrade conduction was found along the anterolateral-to-posterolateral tricuspid annulus in these patients. In this region, the more consistent ability to record an accessory pathway potential from the endocardial than from the epicardial lead is in favor of a subendocardial course of the accessory fiber. The demonstration of earliest preexcited ventricular activation distal to the atrial insertion, as observed in the majority of our patients, is consistent with an insulated bundle coursing from the proximal to the distal insertion of these fibers. These anatomic characteristics, associated with decremental antegrade conduction, closely resemble those of the normal atrioventricular conduction system and might represent a remnant of atrioventricular specialized tissue development. 

Limitations

The mapping and ablation strategy introduced in this study reflects the authors' learning curve in a relatively small series of patients. Consequently, attempts at ablating the ventricular insertion of the accessory fiber as well as atrial pace-mapping and the direct recording of activation potentials to locate the accessory fiber were not systematically continued. However, beginning with patient 4, attempts were made to induce mechanical conduction block in the accessory fiber in a systematic fashion, including repeat sessions in previous patients.

The extensive use of catheter-induced mechanical block as a primary mapping technique requires careful monitoring, because pressure deliberately exerted against the myocardial wall may result in complications. Moreover, although never observed in this study, the resumption of preexcitation after mechanical block may require a long time, thus prolonging procedure duration. Nevertheless, every investigator considering such a procedure should be aware that mechanical block may inadvertently occur when such fibers are mapped to localize either the atrial or the ventricular insertion.

*References 11, 12, 16, 21, 24, 25, 27, 28, 31-36.
Conclusions
The present study confirms previous data showing that in patients with Mahaim-type preexcitation, the involved fibers are mainly right-sided atrioventricular bypass tracts that are preferentially located in the anterolateral-to-posterolateral region, remote from the atrioventricular node. Moreover, strong evidence is given for a reliable and efficacious strategy to ablate these fibers. Catheter-induced mechanical block at the subannular level of the atrial input to the accessory fiber provides an optimal marker for the precise localization of the ablation target site, even during atrial fibrillation, and obviates the need for additional mapping. RF current can readily be delivered at the site of mechanical block after resumption of preexcitation, which generally occurs within a few minutes. Postablation monitoring is advisable, with repeat stimulations performed through an atrial catheter left in place for 24 hours; in cases of recurrence of preexcitation, a repeat procedure can be performed successfully in a simplified procedure using only an ablation catheter advanced to the tricuspid annulus.

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