Localization and Radiofrequency Catheter Ablation of Left-Sided Accessory Pathways During Atrial Fibrillation

Feasibility and Electrogram Criteria for Identification of Appropriate Target Sites

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Objectives. The purpose of the present study was to assess the feasibility of and electrophysiologic criteria for successful radiofrequency catheter ablation of left-sided accessory pathways during atrial fibrillation in patients with Wolff-Parkinson-White syndrome.

Background. The onset of recurrent or sustained atrial fibrillation can complicate or significantly prolong accessory pathway ablation procedures.

Methods. We studied 19 consecutive patients (mean age [±SD] 44 ± 16 years) with Wolff-Parkinson-White syndrome who had ongoing atrial fibrillation with rapid anterograde conduction over the accessory pathway (mean ventricular rate [±SD] 173 ± 26 beats/min, range 130 to 220) at the beginning of the localization procedure during radiofrequency catheter ablation. Localization and ablation of the accessory pathway were performed with a 7F deflectable catheter (4-mm tip) that was placed underneath the mitral valve annulus. The electrophysiologic criteria from unipolar and bipolar local electrograms were compared for successful (n = 18) and unsuccessful (n = 39) sites.

Results. The accessory pathways were localized in the left posteroseptal (n = 6), posterior (n = 1), posterolateral (n = 7) and lateral (n = 5) regions and successfully ablated during atrial fibrillation in 18 (95%) of 19 patients with a mean of 3 ± 2 radiofrequency pulses (range 1 to 8, median 2). Presence of an accessory pathway potential (94% vs. 44%), early activation time of the ventricular electrogram (−3.2 ± 9.2 vs. −15.3 ± 12.6 ms) and recording of atrial activation (88% vs. 61%) from the ablation catheter were helpful in identifying successful sites (p < 0.001, p < 0.001 and p < 0.05, respectively, compared with unsuccessful sites). In addition, the ventricular activation time in relation to the intrinsic deflection of the unipolar electrogram was significantly earlier at successful than unsuccessful sites (18.1 ± 4.8 vs. 24.4 ± 6.6 ms, p < 0.01). A QS complex on the unipolar electrogram was observed at 96% of successful sites and at 94% of unsuccessful sites (p = 0.74). Multivariate logistic regression analysis revealed that the presence of an accessory pathway potential (p < 0.002) and early ventricular activation time in relation to the onset of the QRS complex (p < 0.001) were independent predictors of ablation success.

Conclusions. Localization and radiofrequency catheter ablation of left-sided accessory pathways is possible in patients with sustained atrial fibrillation and rapid anterograde conduction over the accessory pathway during the ablation procedure. The electrophysiologic criteria described here can be used to reliably identify successful sites for radiofrequency ablation.

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the localization and ablation procedure because no standard electrophysiologic study can be performed during atrial fibrillation. Thus, antiarrhythmic drugs are given, or cardioversion is performed, to terminate atrial fibrillation. However, antiarrhythmic drugs are not always effective and may significantly affect the electrophysiologic study. In addition, accessory pathway block might occur after injection of an antiarrhythmic agent, making localization of the pathway impossible. Cardioversion is nearly always effective, but general anesthesia is necessary, and atrial fibrillation may recur, requiring a second cardioversion.

This report presents our experience and electrophysiologic findings in 19 consecutive patients with Wolff-Parkinson-White syndrome in whom the entire localization procedure and ablation of the accessory pathway was attempted during atrial fibrillation with rapid anterograde conduction over the accessory pathway.

Methods

Patients. Nineteen (8.2%) of 231 consecutive patients who underwent radiofrequency catheter ablation of a left-sided accessory pathway at our institution developed sustained atrial fibrillation either spontaneously or during the diagnostic part of the ablation session and formed the study group. All patients were male and had a mean age (±SD) of 44 ± 16 years (range 18 to 77). Seventeen of these 19 patients had a history of sustained orthodromic AV tachycardia. In addition, 16 patients had a history of at least one episode of atrial fibrillation with rapid conduction over the accessory pathway. One patient had permanent atrial fibrillation. Two patients had a history of recurrent syncope, and one was resuscitated from ventricular fibrillation. Sixteen of the 19 patients had no evidence of organic heart disease; 2 had coronary artery disease; and 1 had a secundum atrial septal defect. This patient had undergone previous surgical closure of the atrial septal defect and unsuccessful surgical ablation of the accessory pathway.

Electrophysiologic studies. After written informed consent had been obtained, patients underwent intracardiac electrophysiologic study in a nonsedated and fasting state with conventional techniques of intracardiac recording and stimulation previously reported by our laboratory (2,3) in patients who had sinus rhythm on arrival in the catheterization laboratory, multipolar electrode catheters with interelectrode distances of 5 or 10 mm were introduced percutaneously from peripheral veins and were positioned in the high right atrium, across the tricuspid valve to record the His bundle potential, and in the right ventricular apex. When atrial fibrillation occurred during positioning of the diagnostic catheters, the ablation catheter was inserted, and the patients immediately underwent ablation. Patients who had atrial fibrillation at the beginning of the procedure were treated with the single-catheter technique, as described by Kuck et al. (9). Left ventricular endocardial mapping was performed with a 7F deflectable catheter with a 4-mm tip electrode (Mansfield "Polaris" or Ostrupka "Cerablate,", Dr. P. Ostrupka, Gernzach-Wyhlen, Germany) introduced from the right or left femoral artery. Positioning of the diagnostic catheters and endocardial mapping was performed under biplane fluoroscopy using standard projections (left anterior oblique 30°, right anterior oblique 60°). Intravenous heparin (4,000 to 8,000 U) was administered in all patients during the ablation session. Effective anticoagulation with heparin was continued for 72 h.

Three leads of the surface electrocardiogram (leads I, II, V1), bipolar electrograms from the distal and proximal electrode pairs, respectively, and a unipolar electrogram (filter setting 0.5 to 1,000 Hz, amplification 10 mm/mV) from the distal electrode of the ablation catheter were displayed and recorded simultaneously with a paper speed of 100 or 200 mm/s. Amplification of intracardiac electrograms was –2,000 times (filter setting 40 to 500 Hz). The data were also stored on a multichannel tape recorder for further reproduction.

The amplitude, configuration and timing of the components of the local bipolar electrograms and the unipolar electrograms were determined. Measurements of the time intervals from unipolar and bipolar target site electrograms are illustrated in Figure 1. The local bipolar electrograms obtained from the distal pair of electrodes of the ablation catheter were classified by the presence or absence of atrial activation, the presence or absence of a presumed accessory pathway potential and various time intervals, as described later. The presence or absence of atrial activation or accessory pathway potential recorded bipolar from the ablation catheter was expressed as a discrete variable. Because of the variable extent of the amplitude of the atrial electrogram during atrial fibrillation, the atrial ventricular ratio of the local electrograms was not calculated. Identification of accessory pathway potentials was based on configuration and timing: A sharp, rapid deflection preceding the ventricular component of the local electrogram and inscribing at least 10 ms before the onset of the pre-excited QRS complex in the surface ECG and the intrinsic deflection of the unipolar electrogram were classified as an accessory pathway potential (Fig. 1). In addition, an accessory pathway potential was assumed only when the deflection was distinct from the ventricular component of the electrogram and stable during all pre-excited beats but disappeared during non-pre-excited beats (Fig. 2). The amplitude of the potential and the time interval from the potential to the onset of the pre-excited ORS complex on the surface ECG as well as to the intrinsic deflection of the unipolar electrogram were measured. However, no stimulation studies could be performed during atrial fibrillation to validate that these deflections represent direct activation of the accessory pathway. From the ventricular component of the bipolar electrograms, both the onset of activation and the activation time were calculated as proposed by Colkins et al. (7). The onset of ventricular activation was defined as the first deflection from baseline >30° at a paper speed of 200 mm/s and ventricular activation time as the point of maximal amplitude of the ventricular electrogram (Fig. 1). The time intervals from the ventricular electrogram onset and
Figure 1. Standard lead I of the surface electrocardiogram (ECG), unfiltered unipolar electrogram (UNI) recorded from the tip electrode of the ablation catheter and bipolar electrogram (ABL.) recorded from the distal pair of electrodes of the ablation catheter in a patient with a left posteroseptal accessory pathway obtained directly before successful ablation of the pathway. Onset of pre-excitation (QRSO) is indicated by the vertical line. From the unipolar recording, the intrinsic deflection (ID) and the extent of ST segment elevation (ST) were obtained. Shown by arrows are the Kent potential (K) preceding the local ventricular electrogram (V) as well as the intrinsic deflection. Components of the ventricular electrogram are also indicated (Vo = onset of ventricular electrogram; Va = ventricular activation time).

For analysis of electrogram criteria, the amplitude of the Kent potential was measured as well as the time intervals from the main deflection of the Kent potential to the intrinsic deflection (ΔK – ID) and to QRS onset (ΔK – QRSO). The time intervals from the intrinsic deflection to the point of ventricular activation (ΔID – Va) and the conduction times from QRS onset of the surface ECG to the onset of the local ventricular potential (ΔQRSO – Vo) and the point of ventricular activation (ΔQRSO – Va) were also measured. Irregular atrial activation recorded bipolar from the ablation catheter is clearly present.

The unipolar electrogram obtained from the tip electrode of the ablation catheter was classified by configuration, as proposed by Haissaguerre et al. (8). From the intrinsic deflection, the time intervals to the onset of the pre-excited QRS complex in the surface ECG and to the point of ventricular activation of the local bipolar electrogram were measured. In addition, the extent of ST segment elevation of the unipolar electrogram was determined.

All electrophysiological criteria were analyzed from maximally pre-excited beats. Because the variable extent of pre-excitation resulting in significant changes in unipolar and bipolar electrogram characteristics, criteria for catheter stability could not be reliably obtained.

Radiofrequency ablation. Radiofrequency ablation was performed using a custom-built generator (HAT 2005, Dr. Osypka GmbH) capable of delivering unmodulated 500 kHz at constant adjustable voltage and period. Radiofrequency current was applied between the tip electrode of the ablation catheter and a patch electrode (11 x 16 cm) placed on the back of the patient. Current and impedance were measured and recorded continuously throughout radiofrequency current application. In all patients, radiofrequency current was applied to the ventricular insertion of the accessory pathways. Radiofrequency output power varied between 25 and 50 W. Duration of radiofrequency current application was 60 s; however, at most unsuccessful sites, current application was stopped after 10 to 15 s.

Statistical analysis. Statistical analysis was performed using SPSS software. Continuous variables were compared by Student t test or the Mann-Whitney U test when appropriate, and discrete variables were compared using chi-square analysis. Continuous variables are expressed as mean value ± 1 SD. The 95% confidence intervals for the success and failure rates were calculated using Pearson-Cluoper values. Multivariate stepwise logistic regression was performed to select the group of variables that best predicted outcome. Probability values <0.05 were considered significant.
Table 1. Characteristics of 19 Male Patients. Clinically Documented Arrhythmias, Electrophysiologic Data and Duration and Outcome of Ablation Procedure

<table>
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<tr>
<th>Pt No.</th>
<th>Age (y)</th>
<th>OT</th>
<th>AF</th>
<th>Heart Rate During AF (beats/min)</th>
<th>Shortest RR Interval During AF (ms)</th>
<th>Duration of Ablation Session (min)</th>
<th>Duration of Mapping (min)</th>
<th>No. of RF Pulses</th>
<th>Success</th>
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<td>220 (240°)</td>
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<td>Yes</td>
<td>Posteroseptal</td>
<td>170</td>
<td>260</td>
<td>80</td>
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*aAfter 1 mg/kg body weight of intravenous ajmaline. AF = clinically documented atrial fibrillation; AP = accessory pathway; OT = clinically documented orthodromic tachycardia; Pt = patient; RF = radiofrequency.

Results

Electrophysiologic data and results of radiofrequency catheter ablation. Clinical and electrophysiologic characteristics of the patients are presented in Table 1. In one patient (Patient 2), 1 mg/kg of ajmaline was administered intravenously because of hemodynamic compromise due to fast anterograde conduction over the accessory pathway with a mean ventricular rate of 220 beats/min. Ajmaline slowed the ventricular rate to ~170 beats/min but did not induce anterograde block of the pathway or conversion of atrial fibrillation to sinus rhythm.

The accessory pathways were localized in the left posteroseptal (n = 6), posterior (n = 1), posterolateral (n = 7) and lateral (n = 5) regions of the mitral valve annulus. All patients had predominant or consistent anterograde conduction over the accessory pathway. Mean ventricular rate was 173 ± 26 beats/min (range 130 to 220). The shortest mean RR interval during atrial fibrillation measured 234 ± 41 ms (range 180 to 340). No patient had evidence of a second anterogradely conducting accessory pathway.

A total of 57 radiofrequency pulses were delivered to different endocardial sites. Anterograde accessory pathway conduction was successfully ablated during atrial fibrillation in 18 (95%) of 19 patients (95% confidence interval [CI] for success 0.52 to 0.98, 95% CI for failure 0.006 to 0.25), with a mean of 3 ± 2 radiofrequency applications (median 2, range 1 to 8). There was no significant difference between successful (n = 18) and unsuccessful (n = 39) radiofrequency applications with respect to radiofrequency power delivered (39 ± 11 vs. 34 ± 14 W). Total delivered energy was significantly higher at successful sites (1,292 ± 529 J) than at unsuccessful sites (787 ± 521 J) (p < 0.01). However, this was due to the fact that energy application was stopped prematurely at most unsuccessful sites if anterograde conduction was not interrupted after 10 to 15 s. At successful sites, pre-excitation disappeared within 1 to 8 s (mean 3 ± 2, median 3) after the onset of current delivery (Fig. 3).

Accessory pathway conduction persisted after six radiofrequency pulses applied during atrial fibrillation in only one patient (Patient 12). This patient underwent subsequent electrical cardioversion, and another six radiofrequency pulses were delivered during sinus rhythm to the ventricular insertion of the accessory pathway but were also not effective. Mapping of the atrial insertion of the accessory pathway using the

Figure 3. Successful radiofrequency ablation of a left posterior accessory pathway during atrial fibrillation. Note the disappearance of pre-excitation 1 s after the onset of radiofrequency application (RFC on). HRA = high right atrium; RVA = right ventricular apex.
retrograde approach was then performed during orthodromic tachycardia, and the pathway was ablated with two additional radiofrequency applications.

Duration of the total procedure varied between 60 and 240 min (mean 145 ± 49, median 129); duration of the mapping procedure varied between 5 and 150 min (mean 49 ± 41, median 30), respectively (Table 1). Radiation exposure time varied between 3.5 and 61.7 min (mean 29 ± 17, median 21).

Electrophysiologic criteria to identify successful sites for catheter ablation during atrial fibrillation. To identify successful sites for ablation of accessory pathways during atrial fibrillation, several criteria from unipolar and bipolar electrograms were analyzed (Fig. 1 and 2, Tables 2 and 3). At sites where accessory pathway conduction was successfully ablated, a sharp, rapid deflection preceding the onset of ventricular activation ("Kent potential") was present at 17 (94%) of 18 sites versus 17 (44%) of 39 ineffective sites (p < 0.001). Figures 1 and 2 depict representative examples. The amplitude of these potentials tended to be higher at successful sites (0.8 ± 0.4 vs. 0.4 ± 0.4 mV); however, the difference at unsuccessful sites was not significant (p = 0.069). Irregular atrial activation of changing amplitude was recorded from the ablation catheter at 88% of successful and 61% of unsuccessful sites (p < 0.05).

Onset of local ventricular activation in relation to the pre-excited QRS complex was not significantly different between successful and unsuccessful sites (p = 0.13). However, activation time of the ventricular electrogram in relation to the onset of the pre-excited QRS complex as well as the intrinsic deflection of the unipolar electrogram was significantly earlier at successful versus unsuccessful sites (p < 0.001 and p < 0.01, respectively).

A QS complex on the unipolar electrogram was recorded at nearly all successful and unsuccessful sites (96% vs. 94%, p = 0.744) (Table 2, Fig. 4). The time interval from the intrinsic deflection to the onset of the pre-excited QRS complex tended to be earlier at successful sites than at unsuccessful sites; however, the difference was not significant (p = 0.053). The onset of accessory pathway activation in relation to the intrinsic deflection of a unipolar electrogram was not significantly earlier at successful compared with unsuccessful sites (15.3 ± 4.3 vs. 12.3 ± 6.9 ms, p = 0.177). However, activation time of the ventricular electrogram in relation to the intrinsic deflection was significantly earlier at successful sites (p < 0.01). All other criteria from unipolar or bipolar electrograms, or both, summarized in Table 2, were not significantly different between the two groups.

Using multivariate logistic regression analysis, the independent predictors for outcome of radiofrequency ablation of left-sided accessory pathway during atrial fibrillation were presence of an accessory pathway potential (p < 0.002) and ventricular activation time in relation to the onset of the

| Table 2. Univariate Comparison of Electrophysiologic Variables From Unipolar and Bipolar Electrograms From Successful and Unsuccessful Ablation Sites |
|-----------------|-----------------|--------|
|                 | Successful Sites | Unsuccessful Sites | p     |
|                 | (n = 18)         | (n = 39)         |       |
| Kent potential (%) | 94 | 44 | < 0.001 |
| Kent amplitude (mV) | 0.8 ± 0.4 | 0.4 ± 0.4 | 0.059 (NS) |
| ΔKent - QRS0 (ms) | 25.3 ± 7.6 | 25.6 ± 6.8 | 0.913 (NS) |
| ΔKent - ID (ms) | 15.3 ± 4.3 | 12.36 ± 6.9 | 0.177 (NS) |
| ΔID - QRS0 (ms) | 15.8 ± 4.8 | 9.4 ± 10.9 | 0.532 (NS) |
| ΔID - Va (ms) | 18.1 ± 4.8 | 24.4 ± 6.6 | < 0.01 |
| ΔVa - QRS0 (ms) | 15.6 ± 8.2 | 24.4 ± 8.0 | 0.132 (NS) |
| Atrial activation (%) | 88 | 38 | 0.54 |
| ST elevation (mV) | 2.2 ± 0.9 | 1.9 ± 0.7 | 0.409 (NS) |
| Power (W) | 39 ± 11 | 34 ± 14 | 0.655 (NS) |

Abbreviations as in Figure 1.

| Table 3. Predictive Values of Outcome of Discrete Variables and Combination of Variables for Successful and Unsuccessful Sites |
|-----------------|-----------------|--------|
|                 | Sensitivity (%) | Specificity (%) | Positive Predictive Value (%) | Negative Predictive Value (%) | Accuracy (%) |
| Kent potential | 94 | 56 | 50 | 96 | 68 |
| QS configuration | 94 | 4 | 39 | 50 | 39 |
| Atrial activation | 88 | 38 | 40 | 88 | 54 |
| Combined | 88 | 76 | 70 | 90 | 80 |

Combined = presence of Kent potential, QS configuration and atrial activation; other abbreviations as in Table 2.
pre-excited QRS complex (p < 0.001). Table 3 summarizes the
predictive values of three discrete variables that were analyzed.
The combination of these variables had a high sensitivity (88%) and negative predictive value (90%), a good specificity (76%), positive predictive value (76%) and accuracy (80%).

Electrophysiologic study after ablation and follow-up. In
one patient with permanent atrial fibrillation, no control study
was performed because of recurrence of anterograde accessory
pathway conduction 26 h after successful ablation. This patient
refused a second ablation attempt and was treated with
antiarrhythmic drugs. One additional patient who was success-
fully treated refused a control study. No pre-excitation was
documented in the surface ECG. A control electrophysiologic
study was performed in both patients with palpitations but no
documented arrhythmias 9 and 12 months after the successful
ablation. Both patients had no evidence for recurrence of
accessory pathway conduction.

Discussion

Background and main findings of the study. The occur-
dence of atrial fibrillation during an electrophysiologic study or
during catheter ablation in patients with accessory pathways is
a common problem. In our series, sustained atrial fibril-
dation during radiofrequency ablation of left-sided accessory
pathway occurred in 19 (8.2%) of 231 patients during the
enrollment period of this study. In patients with sustained
atrial fibrillation, it is often time-consuming to terminate atrial
fibrillation by drugs or electrical cardioversion, and in some
patients atrial fibrillation cannot be terminated by drugs or
repeatedly recurs after electrical cardioversion. Thus, on the
basis of our experience of successful radiofrequency ablation
of accessory pathways during sinus rhythm in >300 patients,
we decided to attempt ablation of accessory pathways during
atrial fibrillation. The results of the present study clearly show
that localization and radiofrequency catheter ablation of left-
sided accessory pathways during atrial fibrillation is feasible. In
addition, the results include findings in a total of 19 consecu-
tive patients, a fairly large group that also allowed a detailed
analysis of local electrogram criteria from unipolar and bipolar
electrogram recordings to identify successful target sites for
radiofrequency ablation of left-sided accessory pathways dur-
ing atrial fibrillation.

Radiofrequency ablation of accessory pathways during
atrial fibrillation. Successful localization and catheter abla-
tion of accessory pathways in patients with Wolff-Parkinson-
White syndrome during atrial fibrillation has not yet been
reported. Kunze et al. (10) have described one patient in whom
radiofrequency catheter ablation was successfully performed
during atrial fibrillation. However, in this patient, the pathway
was localized during sinus rhythm (10). Haissaguerre et al. (11)
evaluated a series of patients with Wolff-Parkinson-White
syndrome in whom atrial fibrillation was induced to con-
figure the configuration of the maximally pre-excited QRS com-
plex with that during stimulation with the ablation catheter at
the suspected site of the accessory pathway insertion. However, in
these patients, the accessory pathways were localized during
sinus rhythm before the induction of atrial fibrillation (8).
Thus, we believe that the present study is the first to show that
precise localization and radiofrequency catheter ablation of
accessory pathway is possible during atrial fibrillation with a
success rate as high as that achieved with ablation of left-sided
accessory pathways during sinus rhythm (1,4,5). Only one of
the 19 patients was unsuccessfully treated during atrial fibril-
lation. In this patient, it was also impossible to ablate the
ventricular insertion of the accessory pathway during sinus
rhythm, suggesting an atypical intramural or even epicardial
insertion of the pathway. Ablation at the atrial insertion of the
pathway was finally successful in this patient. When the results of the present study are compared with those of others (1,4,5) and our previous results for radiofrequency ablation of accessory pathways during sinus rhythm or induced orthodromic tachycardia with respect to number of radiofrequency impulses delivered and procedural and fluoroscopic duration, it appears that the procedure can be performed relatively fast and with fewer radiofrequency impulses during atrial fibrillation. Most important, no significant complications occurred during the ablation session. Some patients were transiently and mildly hemodynamically compromised during the first few minutes after the onset of atrial fibrillation. However, other than intravenous administration of ajmaline to slow anterograde accessory pathway conduction in one patient, no interventions were necessary in the others.

**Electrophysiologic criteria for catheter ablation of accessory pathways during atrial fibrillation.** Several groups have reported criteria for the identification of successful target sites for catheter ablation of accessory pathways if mapping is performed during sinus rhythm or orthodromic tachycardia (2,7,8). From these studies it can be concluded that the presence of an accessory pathway potential and the timing of the local ventricular electrogram relative to the QRS complex of pre-excited beats are the most powerful predictors for successful ablation. In general, the present study shows that the same holds true for ablation of accessory pathways during atrial fibrillation. The incidence of accessory pathway potential recordings at successful ablation sites in the present study is higher than that reported by others (2,8). However, this might at least in part be due to the fact that measurements in this study were performed during maximally pre-excited beats, which might increase the likelihood of accessory pathway potential recording. In addition, there was a trend toward higher accessory pathway potential amplitudes at successful versus unsuccessful sites, suggesting a closer proximity of the ablation catheter to the accessory pathway. The time interval between the accessory pathway potentials and the onset of the pre-excited QRS complex was not significantly different in both groups. Similar to a previous analysis of Calkins et al. (7), the onset of the ventricular potential in relation to the QRS complex lacks predictive power for ablation success. This might be due to the well known effects of far field electrical activity on bipolar electrogram onset. However, the activation time of the local ventricle as assessed by the major deflection of the bipolar electrogram is also evident from the unipolar electrogram as a landmark compared with the onset of the pre-excited QRS complex, which is sometimes difficult to assess, especially during atrial fibrillation with fast but irregular anterograde conduction over the accessory pathway. As shown in Table 2, measurements of activation time of the ventricular electrogram in relation to the intrinsic deflection of the unipolar electrogram as a landmark compared with the onset of the pre-excited QRS complex, which is sometimes difficult to assess, especially during atrial fibrillation with fast but irregular anterograde conduction over the accessory pathway. As shown in Table 2, measurements of activation time of the ventricular electrogram in relation to the intrinsic deflection of the unipolar electrogram were very useful for the identification of appropriate target sites for ablation. Because the unipolar electrogram can be very quickly and easily interpreted, the first step of the mapping procedure in the present study was based mainly on the configuration of the unipolar electrogram. All sites with a QRS and most sites with a QS pattern were disregarded. Whenever the unipolar electrogram indicated a close position of the ablation catheter to the accessory pathway, as evident from a QRS configuration, mapping criteria from the bipolar electrograms were applied. The catheter was manipulated very carefully within this area until a high amplitude accessory pathway potential could be identified inscribing at least 10 ms before the intrinsic deflection of the unipolar electrogram and atrial activation recorded bipolar from the ablation catheter was present. These three criteria combined had a high sensitivity and negative predictive value and a fairly good specificity, positive predictive value and accuracy. The high success rate with a median of two radiofrequency pulses delivered and the relatively short duration of the whole ablation procedure clearly show that the approach described in this report can be recommended for ablation of left-sided accessory pathways during atrial fibrillation.

**Study limitations.** Our data show that catheter ablation of overt left-sided accessory pathways during atrial fibrillation can be performed relatively fast and with a high success rate. However, this does not imply that the procedure can be
The effects of catheter ablation on the retrograde conduction of the accessory pathway cannot be assessed during atrial fibrillation, and in the present study a second electrophysiologic test was necessary to confirm retrograde block of the accessory pathway with the disadvantage of a longer hospital period. To avoid this disadvantage, it might be reasonable to have patients undergo electrical cardioversion at the end of the ablation procedure and immediately assess retrograde conduction. However, because only 1 of 18 patients undergoing ablation during atrial fibrillation had evidence for recurrence of retrograde accessory pathway conduction during the electrophysiologic study performed 4 to 6 days after ablation, it seems reasonable to rely solely on the surface ECG to detect anterograde accessory pathway conduction and on the clinical follow-up instead of performing an early repeat electrophysiologic study. In accordance with a recent analysis (12) on recurrence of accessory pathway conduction after successful radiofrequency catheter ablation, we currently do not perform a predischarge or late electrophysiologic control study after ablation in patients free of arrhythmias and without evidence of accessory pathway conduction recurrence in the surface ECG, whether or not ablation was performed during sinus rhythm or atrial fibrillation.

The electrophysiologic criteria described in the present study to identify successful ablation sites are valid for ablation of left-sided accessory pathways only. Although our initial experience with radiofrequency catheter ablation of right-sided accessory pathways during atrial fibrillation indicates that comparable criteria can be used to identify successful sites, experience in a larger patient group is necessary to confirm these findings (13).

It is well known that atrial fibrillation with rapid conduction over the accessory pathway can severely compromise the patient and may on rare occasions induce ventricular fibrillation. Thus, it is necessary to proceed cautiously and to be aware of this complication. No complications were observed in this study; however, the number of patients included is relatively small, and further experience is required to ensure the safety of this procedure.

Application of multiple radiofrequency pulses to adjacent sites as performed in some patients in this study might have significantly affected analysis of the local electrograms. An analysis in a subgroup of patients who had successful ablation with a single radiofrequency pulse (6 [32%] of 19 patients) revealed that the criteria for ablation success are not different from those for ablation with multiple pulses. However, the group of patients with single-pulse ablation was too small to allow a statistical comparison with the other patients.

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References