Anatomic, Electrical, and Mechanical Factors Affecting Bipolar Endocardial Electrograms

Impact on Catheter Ablation of Manifest Left Free-Wall Accessory Pathways

Riccardo Cappato, MD; Michael Schlüter, PhD; Lluis Mont, MD; Karl-Heinz Kuck, MD

Background. The use of bipolar endocardial electrogram characteristics to guide radiofrequency (RF) current catheter ablation of accessory pathways (APs) has been advocated by several investigators. However, the influences of a varying anatomy of the AP and the atrioventricular groove, of different ablative approaches, and of RF current pulses preceding the final pulse have not been adequately addressed.

Methods and Results. Local bipolar endocardial electrograms were retrospectively analyzed in a uniform cohort of 62 consecutive patients with a single manifest AP located on the left free wall; in all patients, the AP had been ablated by a uniform approach with a single catheter advanced retrogradely toward the mitral annulus. Electrogram parameters assessed were the presence or absence of a presumed AP potential, the atrial-to-ventricular (A/V) amplitude ratio, the A-V interval, and the onset of delta wave to local ventricular activation (Δ-V) interval. The AP location was classified on fluoroscopy as anterior, lateral, or posterior. Catheter stability was verified by comparing pre- and post-RF amplitudes of local atrial potentials. The ablation site was ventricular in 52 patients (group A) and atrial in 10 (group B). In group A, 26 APs (50%) required a single RF current pulse for ablation. These APs showed no anatomic predilection and no statistically significant differences in electrogram parameters from 24 APs that were ablated only after a median of three pulses had failed, suggestive of a wider ventricular insertion of the latter APs. A lower A/V ratio and a higher incidence of transient AP block found in the remaining 2 group A patients, who had anteriorly located APs requiring >10 failed pulses, suggested an adverse anatomy of the A-V groove in that region. A stepwise multivariate logistic regression analysis revealed that the simultaneous presence of (1) a presumed AP potential, (2) an A/V ratio ≥0.10, (3) an A-V interval ≤40 milliseconds, and (4) a Δ-V interval ≤0 milliseconds was associated with a specificity of 94% and a positive predictive accuracy of 87% for an RF pulse to be successfully applied to the ventricular insertion to the AP. Compared with APs of group A, APs of group B were distinguished by unsuccessful ventricular pulses associated with a Δ-V interval >10 milliseconds in the presence of an A/V ratio >0.33 (specificity of 97% and positive predictive accuracy of 82%), which is suggestive of a more epicardial ventricular insertion of these APs.

Conclusions. The effect of anatomic variations of the AP and the A-V groove is reflected in the bipolar endocardial electrogram and needs to be considered in the approach to AP ablation. The stepwise inclusion of the four electrogram criteria introduced in this study may improve the efficacy of RF catheter ablation of a manifest left free-wall AP at its ventricular insertion. Whenever mapping cannot improve on a Δ-V interval >10 milliseconds despite apparently close contact with the mitral annulus ("good" A/V ratio), attempts at ablation are likely to be successful at the atrial aspect of the mitral annulus. (Circulation. 1994;90:884-894.)

Key Words • electrocardiography • catheter ablation • radiofrequency

Catheter ablation using radiofrequency (RF) energy to ablate an accessory atrioventricular connection is increasingly being used as the primary therapeutic option for patients with the Wolff-Parkinson-White syndrome.1-6 In manifest left-sided free-wall accessory pathways, the "single-catheter" approach has recently been introduced to simplify the technique and reduce radiation exposure time.7,8 Although highly effective, this approach is associated, as is any other approach reported to date, with a varying number of unsuccessful pulses preceding the final (successful) pulse; this in turn could relate to complications. Therefore, markers of a successful outcome are highly desirable.

Previous studies have addressed this crucial aspect,9-12 and predictors of a successful pulse have been identified, such as local electrogram stability, the presence of a presumed accessory pathway activation potential, the timing of local atrial relative to local ventricular activation, and the timing of local ventricular activation relative to the onset of the QRS complex. A major limitation of these reports is that the accessory pathway is regarded as a uniform entity. The statistical analyses applied to local electrogram parameters to predict the outcome of an RF current pulse did not take into account a number of important variables likely to condition the outcome of any single RF current application. Those are the anatomy of the atrioventricular groove, the anatomy and location of the accessory pathway, and the orientation of the catheter electrodes with respect to the presumed course of the accessory pathway.13-15 Furthermore, parameters indicative of electrogram stability have only been evaluated before, rather than before and after, RF current application, and the correlation between the cumulative amount of electrical
energy delivered and the outcome, as well as the analysis of transient accessory pathway block, have been inadequately addressed thus far.

The present study was therefore designed to retrospectively assess the predictive value of an analysis of local electrograms that takes the anatomic and technical complexity of accessory pathway ablation into account. In an attempt to provide a fairly uniform setting, a selected group of patients was chosen whose accessory pathway was ablated by the same approach in each patient.

Methods

Patients

Sixty-five consecutive patients with manifest preexcitation on the surface ECG due to a single left free-wall accessory pathway underwent attempts at single-catheter RF current ablation over a 22-month period. Three patients were excluded from the analysis because accessory pathway mapping could not be successfully completed without reverting to the multiple-catheter technique. The remaining 62 patients (21 women; age, 36±16 years; [range, 4 to 67] years) were included in this study. They were free of organic heart disease. All patients were symptomatic, with symptoms ranging from frequent episodes of palpitations and dizziness to syncope (7 patients) and cardiac arrest (8 patients). The clinically documented arrhythmias were atrioventricular reentrant tachycardia in 41 patients, atrial fibrillation in 10, and both types of arrhythmia in 9; in 2 patients, no tachyarrhythmia was documented. Medical therapy with up to six (median, two) antiarrhythmic agents had failed in the majority of cases; 13 patients had not received antiarrhythmic agents. No patient had previously undergone a diagnostic electrophysiologic investigation.

Strategy of Catheter Mapping and Ablation

All electrophysiologic studies were performed by the same investigator (K.H.K.). The mapping procedure used in our laboratory has been described in detail elsewhere. Briefly, a deflectable, 4-mm-tip electrode catheter with a 2-mm inter-electrode distance (Boston Scientific International, or OSCOR Medical Corp) was introduced through the right femoral artery into the left ventricle toward the mitral valve and placed below the annulus (ventricular approach 14) such that a bipolar electrogram recorded from the distal electrode pair revealed both a distinct ventricular and an atrial potential. During sinus rhythm, the catheter was used to locate along the mitral annulus the site of the shortest atrium-to-ventricle (A-V) interval and to search for a presumed accessory pathway activation potential in that annular region in which the delta-wave pattern of the patient's surface ECG suggested the location of the pathway.16,17 According to the catheter position at the site of ablation, as assessed in the 30° left anterior oblique fluoroscopic view, anatomic pathway location was categorized as anterior, lateral, or posterior.15 Target sites for ablation of accessory pathways were identified by early ventricular activation relative to the onset of the delta wave, and/or a presumed accessory pathway activation potential preceding the QRS complex.

Electrocoagulation was attempted with a 500-kHz generator (HAT 200; OSCOR Medical Corp.). RF current at power settings of 20 to 30 W was delivered for between 20 and 30 preset seconds during sinus rhythm in a unipolar fashion (distal catheter electrode to patch electrode on the patient’s back). After several unsuccessful RF current applications from a subannular position, the ablation catheter was advanced across the mitral annulus and positioned at a supra-annular level whenever the investigator felt that further applications at the former site were unlikely to result in accessory pathway conduction block. A supra-annular catheter position was verified by an A-V amplitude ratio of at least 1, associated fluoroscopically with a “wagging” movement of the catheter tip in concert with heart motion.

After the final RF current pulse, a standard 6F quadrupolar catheter was introduced into the right ventricle through a sheath in the right femoral vein placed at the beginning of the study for heparinization and the administration of sedative drugs; by use of this catheter, the absence of retrograde accessory pathway conduction was ascertained by the extra-stimulus technique. The stimulation catheter was then withdrawn and positioned in the right atrium for stimulation at increasing rates to exclude the presence of a second accessory pathway capable of anterograde conduction.

An RF current pulse was considered successful if it resulted in permanent bidirectional block in the accessory pathway. An RF current pulse was considered unsuccessful if it had no apparent effect on anterograde accessory pathway conduction or resulted in transient anterograde accessory pathway conduction block only. Ablation of an accessory pathway was usually followed within 1 minute by the application of an additional “safety” pulse to the same site, to minimize the possibility of late recurrence of accessory pathway conduction.

Recording Techniques

Local electrograms were filtered at 50 to 500 Hz and amplified at a gain of 20 mm/mV with a 16-channel recorder (Mingograph, Siemens AG) at carrier speeds of 100 to 250 mm/s.

Evaluated Parameters

Every application of RF energy was evaluated. Excluded from the analysis were safety applications and unsuccessful pulses delivered from the atrial aspect of the mitral valve. Also, ventricular pulses resulting in catheter displacement or a sudden impedance rise were generally left out of the analysis, except for those in which catheter displacement or impedance rise was delayed such that (transient) conduction block occurred within ±1 SD of the mean time to permanent block. These pulses were considered “potentially successful” and were added to the actually successful pulses in a subanalysis that attempted to assess the conditioning role of the local electrogram parameters in predicting a successful outcome with regard to the anatomic area.

During mapping, an accessory pathway potential was assumed if a distinct potential following the local atrial potential was recorded that preceded, or coincided with the onset of the delta wave and was followed by a third potential representing local ventricular activation. It was noted whenever this potential had a specific morphology, i.e., a distinct “up-down-up” configuration inscribed between the offset of the atrial potential and the onset of the local ventricular deflection. This type of potential was called “Zorro” potential, because it resembles the letter “Z” rotated counterclockwise by 45° (Figure). Because just one catheter was used, the nature of the potential theories, to originate from an accessory pathway could not be validated by stimulation techniques. The disappearance of this potential after a successful RF pulse or a pulse resulting in a transient block, with unchanged timing and morphology of the atrial potential, was regarded as further proof of its accessory pathway origin (Figure).

The following electrogram parameters were assessed: Whenever an accessory pathway potential was present before a current application, the local atrium–accessory pathway (A–AP) interval and the local accessory pathway–ventricle (AP–V) interval were assessed; in any case, the local A–V interval, the onset of delta wave to local ventricular activation (Δ–V) interval, the amplitude ratio (A/V) of local atrial and ventricular potentials before each pulse, and the amplitudes of local atrial and ventricular potentials were assessed before and after each pulse to determine the preapplication to postappli-
Preablation and postablation electrograms recorded from a patient with a left lateral accessory pathway (AP). Shown are surface ECG leads II and III and a bipolar endocardial electrogram recorded through the distal electrode pair of the mapping/ablation catheter at the left ventricular (LV) insertion of the accessory pathway. Left, A distinct potential, originating from accessory pathway activation, is inscribed between the local atrial (A) and ventricular (V) potentials. Note “Zorro”-type morphology of the accessory pathway potential interposed between A and V potentials. Vertical line depicts the onset of the delta wave, which is preceded by local V activation. The A-AP and delta-V intervals are 25 and 5 milliseconds, respectively; the A-V interval is 40 milliseconds; and the A/V amplitude ratio is 0.43. Right, Note postablation disappearance of AP potential. The postablation A-V interval is 120 milliseconds. Also note corresponding morphologies of A potential in both panels. Pre-A/post-A amplitude ratio is 1.2.

Statistical Analysis

Data are presented as mean±1 SD or as median values, where appropriate. Comparisons between continuous variables were analyzed with the Mann-Whitney U test and Student’s t test, or Wilcoxon’s nonparametric test, when required. Nominal data were analyzed with the χ² test. A multivariate logistic regression analysis was performed to determine, at the ventricular insertion of the accessory pathway, (1) the influence on the successful outcome of an RF current application of four independent criteria: (a) the recording of a presumed accessory pathway potential; (b) an A/V ratio ≥0.1; (c) an A-V interval ≤40 milliseconds; and (d) a Δ-V interval ≤0 milliseconds; and (2) the influence of a Δ-V interval >10 milliseconds and an A/V ratio >0.33 on an unsuccessful application of RF current to the ventricular insertion of an accessory pathway that was eventually ablated at its atrial insertion.

For the former analysis, it was assumed that the logarithmic odds in favor of a successful application can be expressed as a linear combination of the four criteria Xᵢ (i=1, ..., 4; with Xᵢ=1 if the respective criterion is fulfilled, and Xᵢ=0 if it is not fulfilled):

\[ \log[\text{odds (success)}] = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 = \Sigma \beta_i X_i \]

Thus, the coefficients βᵢ denote the relative weight of each criterion’s contribution to the odds. From these coefficients, an odds ratio

\[ \text{OR} = \exp(\Sigma \beta_i - \Sigma \beta_m) \]

may be calculated that gives the chance of success in the presence of n criteria fulfilled compared with m criteria fulfilled. The latter logistic regression analysis with only two criteria was performed in an analog fashion. The potential influence of an unsuccessful pulse on the subsequent pulse(s) was not taken into account for either regression analysis. A probability value of <0.05 was considered statistically significant. Standard formulas were used to calculate sensitivity, specificity, and positive and negative predictive accuracy.

Results

General Ablation Data

A single left-sided free-wall accessory pathway was found in all patients. In 52 patients, RF current application to the ventricular insertion abolished accessory pathway conduction in both the anterograde and retrograde directions (group A). In 10 patients, abolition of accessory pathway conduction was achieved by RF current application at the atrial accessory pathway insertion (group B), after 1 to 6 (median, 3) unsuccessful applications at the ventricular insertion. The sessions lasted for 1.5±0.7 hours in group A and 1.8±0.7 hours in group B (difference statistically not significant [NS]); fluoroscopy time was significantly less in group A patients than in group B patients (15.8±11.2 versus 29.0±17.3 minutes; P<0.01).

A total of 266 RF current pulses were delivered. After 63 safety pulses, 6 unsuccessful pulses delivered from the atrial aspect of the mitral valve, 8 (unsuccessful) ventricular pulses producing a sudden impedance rise, and 30 pulses during which the catheter became fluoroscopically dislodged without producing accessory pathway block were disposed of, 157 ventricular RF current pulses remained for analysis. Of these, 52 were successful and 72 unsuccessful in group A, and 33 were unsuccessful ventricular pulses in group B. In group A, the mean power and application time of successful pulses did not differ statistically from those of unsuccessful pulses (25.1±5.9 versus 25.6±4.4 W and 20.6±5.9 versus 22.6±8.3 seconds). Mean power and application time of unsuccessful pulses in group B (23.8±4.2 W and 20.5±5.2 seconds, respectively) did not differ statistically from those of unsuccessful pulses in group A.

With regard to the number of unsuccessful pulses, group A was further divided into three subgroups; 26 accessory pathways were ablated with just one pulse (no unsuccessful pulses; subgroup A1), 24 accessory pathways required 2 to 7 applications (1 to 6, unsuccessful pulses, median 3; subgroup A2), while for 2 pathways, 11 and 12 applications were required, respectively (≥10 unsuccessful pulses; subgroup A3). A median of 3 (range, 2 to 10) unsuccessful ventricular pulses were delivered in group B patients.

Electrogram Parameters

All measurements pertaining to the analysis of local electrogram parameters are summarized in Tables 1 and 2.


### Table 1. Electrogram Parameters of Successful and Unsuccessful Radiofrequency Current Pulses

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S/U</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording of a presumed accessory path potential</td>
<td>S</td>
<td>49/52 (94%)</td>
<td>7/10 (70%)</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>52/72 (72%)*</td>
<td>27/33 (82%)</td>
</tr>
<tr>
<td>A/V amplitude</td>
<td>S</td>
<td>0.29±0.18</td>
<td>4.0±3.00</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>0.23±0.16*</td>
<td>0.27±0.15</td>
</tr>
<tr>
<td>A-V interval (ms)</td>
<td>S</td>
<td>37±6</td>
<td>50±4</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>40±7*</td>
<td>44±9†</td>
</tr>
<tr>
<td>Δ-V interval (ms)</td>
<td>S</td>
<td>2±7</td>
<td>8±9</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>4±8</td>
<td>12±10†</td>
</tr>
</tbody>
</table>

S indicates successful; U, unsuccessful; A/V, atrioventricular; A-V, atrium-to-ventricular; and Δ-V, onset of delta wave to local ventricular activation. All U pulses were delivered from a ventricular catheter position, as were the 52 S pulses in group A patients. The 10 S pulses in group B patients were delivered from an atrial catheter position.

*P<.05 vs S pulses; †P<.05 vs U pulses in group A.

### Recording of a Presumed Accessory Pathway Potential

In group A, a presumed accessory pathway potential was recorded in 49 successful pulses (94%) and in 52 pulses that were unsuccessful (72%) (Table 1). In the 49 successful pulses, the presumed accessory pathway potential was no longer apparent in the postablation electrogram recorded by the ablation catheter (Figure). No differences were observed in the incidence of a presumed accessory pathway potential recording either among the successful pulses in subgroups A1, A2, and A3 or between the unsuccessful pulses in subgroups A2 and A3 (Table 2). In group B, 27 (82%) of the 33 unsuccessful pulses were preceded by a presumed accessory pathway potential. The incidence of this parameter in unsuccessful pulses of groups A and B was statistically not different.

### Morphology of the Accessory Pathway Potential

In group A, a "Zorro"-type accessory pathway potential was seen in 47 successful (90%) and in 48 failed pulses (69%; P<.05), for positive and negative predictive accuracies of 49% and 83%, respectively. In group B, such a potential was observed in 22 (67%) of the unsuccessful ventricular pulses.

### A/V Ratio

In group A, the local A/V ratio was larger in successful than in unsuccessful pulses (0.29±0.18 versus 0.23±0.16; P<.05). Among pulses preceded by the recording of a presumed accessory pathway potential, an A/V ratio ≥0.1 was significantly more often observed in successful than in unsuccessful pulses (47 of 49 versus 32 of 52; P<.001). The A/V ratios of successful pulses were statistically not different in the subgroups A1, A2, and A3. It is noteworthy, though, that A/V ratios as low as 0.12 and 0.14 were found in 2 successful pulses of subgroup A3. For unsuccessful pulses, a significantly lower A/V ratio was found in subgroup A3 (median, 0.08) compared with subgroup A2 (mean, 0.27; P<.05).

In group B, the mean local A/V ratio at the ventricular unsuccessful sites was statistically not different from that of subgroup A2 but was, correspondingly, higher than that of subgroup A3 (P<.01).

### A-V Interval

In group A, the local A-V interval was shorter at sites of successful pulses than at sites at which pulse delivery was unsuccessful (37±6 versus 40±7 milliseconds; P<.05). In the 3 patients in whom pulse delivery was successful in the absence of a presumed accessory pathway potential, the local A-V intervals were 30 milliseconds in 2 and 35 milliseconds in 1; a local A-V interval ≤40 milliseconds was also found in 14 of 20 unsuccessful attempts without a presumed accessory pathway potential. Among the pulses in which an accessory pathway potential was present and an A/V ratio ≥0.1 was measured, there was a significantly higher proportion of successful pulses (38 of 47 versus 16 of 32; P<.01) associated with an A-V interval ≤40 milliseconds.

For successful pulses, the local A-V interval was statistically not different in subgroups A1 and A2. No difference was found between unsuccessful pulses of subgroups A2 and A3.

The local A-V interval of unsuccessful pulses, at 44±9 milliseconds, was significantly higher in group B than in group A (P<.05).

### Table 2. Electrogram Parameters of Successful and Unsuccessful Radiofrequency Current Pulses in Subgroups A1, A2, and A3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S/U</th>
<th>Subgroup A1</th>
<th>Subgroup A2</th>
<th>Subgroup A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording of a presumed accessory path potential</td>
<td>S</td>
<td>24/26 (92%)</td>
<td>23/24 (96%)</td>
<td>2/2 (100%)</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>34/53 (64%)*</td>
<td>15/19 (79%)</td>
<td></td>
</tr>
<tr>
<td>A/V amplitude</td>
<td>S</td>
<td>0.26±0.16</td>
<td>0.33±0.17</td>
<td>0.12; 0.14</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>0.27±0.15</td>
<td>0.08 (0.04-0.67)†</td>
<td></td>
</tr>
<tr>
<td>A-V interval (ms)</td>
<td>S</td>
<td>37±7</td>
<td>36±6</td>
<td>40; 55</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>40±8*</td>
<td>41±6</td>
<td></td>
</tr>
<tr>
<td>Δ-V interval (ms)</td>
<td>S</td>
<td>3±8</td>
<td>1±7</td>
<td>0; 5</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>5±6*</td>
<td>3±7</td>
<td></td>
</tr>
</tbody>
</table>

S indicates successful; U, unsuccessful; A/V, atrioventricular; A-V, atrium-to-ventricular; and Δ-V, onset of delta wave to local ventricular activation. Subgroup A1 had no U pulses preceding the S pulse; subgroup A2, a median of 3 U pulses preceding the S pulse; and subgroup A3, ≥10 U pulses preceding the S pulse.

*P<.05 vs S pulses; †P<.05 vs U pulses in subgroup A2.
TABLE 3. Variables Used in the Logistic Regression Analyses With Corresponding \( \beta \)-Coefficients and \( P \) Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \beta )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Successful outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recording of a presumed accessory pathway potential</td>
<td>2.517</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>A/V amplitude ratio ( \geq 0.1 )</td>
<td>2.643</td>
<td>.001</td>
</tr>
<tr>
<td>A-V interval ( \leq 40 ) ms</td>
<td>1.326</td>
<td>.007</td>
</tr>
<tr>
<td>( \Delta-V ) interval ( \leq 0 ) ms</td>
<td>1.335</td>
<td>.004</td>
</tr>
<tr>
<td>B. Unsuccessful outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta-V ) interval &gt;10 ms</td>
<td>2.003</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>A/V amplitude ratio &gt;0.33</td>
<td>1.163</td>
<td>0.019</td>
</tr>
</tbody>
</table>

A/V indicates atrial-to-ventricular; A-V, atrium-to-ventricle; and \( \Delta-V \), onset of delta wave to local ventricular activation. A, For the successful outcome of a pulse delivered from a ventricular catheter position. B, For the unsuccessful outcome of a pulse delivered from a ventricular catheter position to an accessory pathway that was eventually ablated from the atrium.

\( \Delta-V \) Interval

In group A, the local \( \Delta-V \) interval was shorter in successful than in unsuccessful pulses (\( 1\pm7 \) versus \( 5\pm6 \) milliseconds; \( P<.05 \)) only for patients composing subgroup A2. When those of subgroup A3 were included, this difference was still present, but statistically no longer significant. Among the pulses in which a presumed accessory pathway potential was recorded, the A/V ratio was \( \geq 0.1 \), and the A-V interval was \( \leq 40 \) milliseconds, there was a significantly higher proportion of successful pulses (26 of 48 versus 4 of 16; \( P<.01 \)) associated with a \( \Delta-V \) interval \( \leq 0 \) milliseconds.

No differences were found among subgroups A1, A2, and A3 in the local \( \Delta-V \) interval of successful pulses and among subgroups A2 and A3 in the local \( \Delta-V \) interval of unsuccessful pulses.

In group B, the local \( \Delta-V \) interval at unsuccessful sites was \( 12\pm10 \) milliseconds, which was significantly larger than in unsuccessful group A pulses (\( P<.05 \)). A local \( \Delta-V \) interval >10 milliseconds was recorded in 18 unsuccessful group B pulses (55%) but in only 9 unsuccessful group A pulses (13%; \( P<.01 \)). Among pulses preceded by the recording of a \( \Delta-V \) interval >10 milliseconds, a significantly higher proportion of unsuccessful pulses in group B was associated with a local A/V ratio >0.33 (9 of 18 versus 1 of 9 in group A; \( P<.05 \)).

Stepwise Regression Analysis

In group A, the multivariate logistic regression analysis revealed that the recording of a presumed accessory pathway potential, the presence of an A/V ratio \( \geq 0.1 \), an A-V interval \( \leq 40 \) milliseconds, and a \( \Delta-V \) interval \( \leq 0 \) milliseconds all had an independent and statistically significant influence on the odds in favor of a successful outcome of an RF current application (Table 3). For instance, compared with the situation in which none of these criteria were fulfilled, the chance of a successful pulse delivery in the presence of a presumed accessory pathway potential was increased by a factor of \( \exp(\beta_5)=\exp(2.517)=12.4 \). The odds ratios for a successful outcome, as well as the sensitivities, specificities, and positive and negative predictive accuracies related to the stepwise inclusion of the four electrogram criteria, in the sequence introduced above, are given in Table 4. When all criteria were fulfilled, the specificity and the positive predictive accuracy were 94% and 87%, respectively.

Logistic regression analysis also revealed that a \( \Delta-V \) interval >10 milliseconds had an independent and statistically significant influence on the odds in favor of a ventricular pulse to be unsuccessful in the presence of an accessory pathway that was eventually ablated from the atrium (Table 3). This finding implies that the chance of an unsuccessful pulse to fall into group B was increased by a factor of \( \exp(2.003)=7.4 \) if the \( \Delta-V \) interval was >10 milliseconds. The specificity and positive predictive accuracy of this criterion were 88% and 67%, respectively (Table 4). Unsuccessful group B pulses were also inde-
Table 5. Number of Successful and Unsuccessful Pulses Delivered to Three Different Anatomic Regions, Differentiated by Patient Groups

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1</td>
<td>A2</td>
</tr>
<tr>
<td>Successful pulses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Lateral</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Posterior</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Unsuccessful pulses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>Lateral</td>
<td>35</td>
<td>...</td>
</tr>
<tr>
<td>Posterior</td>
<td>2</td>
<td>...</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>19</td>
</tr>
</tbody>
</table>

With the exception of the 10 successful group B pulses, all pulses were delivered from a ventricular catheter position.

independently influenced by an A/V ratio >0.33 (Table 3), meaning that when both criteria were fulfilled for an unsuccessful pulse, its chance to belong in group B was increased by a factor of \( \exp(2.003+1.163) = \exp(3.166) = 23.7 \). Specificity and positive predictive accuracy for this situation were 97% and 82%, respectively (Table 4).

Anatomic Site of Accessory Pathways

In group A, the location of the ventricular accessory pathway insertion was anterior in 15, lateral in 32, and posterior in 5 patients (Table 5). Local electrogram parameters of successful and unsuccessful pulses were statistically not different for these three regions.

The number of unsuccessful pulses given per patient in subgroup A2 was statistically not different in the three anatomic regions. In both patients composing subgroup A3, the accessory pathway was located anteriorly.

When the 6 “potentially successful” pulses in group A2 and A3 patients—due to catheter displacement (5 pulses in the anterior region, 1 in the lateral) or a sudden impedance rise (1 pulse each in the anterior and lateral regions)—were added to the permanently effective pulses, all successful pulses delivered in the anterior area were associated with longer A-V (37.7±7.0 versus 36.6±6.0 milliseconds, \( P<.01 \)) and Δ-V intervals (3.5±8.0 versus 1.6±6.0 milliseconds, \( P<.01 \)) than those delivered in the lateral area. This difference was not found when only permanently effective pulses were taken into account.

In group B, the ventricular insertion of the accessory pathway was anterior in 3, lateral in 6, and posterior in 1. The distribution of accessory pathways and the number of unsuccessful pulses given per patient and anatomic region were statistically not different from those in group A.

Accessory Pathway Conduction Block

In group A, permanent conduction block in the accessory pathway set in significantly earlier than a conduction block that turned out to be transient (3.0±2.5 versus 7.2±5.2 seconds; \( P<.001 \)). Conduction block in the anterior region occurring later than 13 seconds was never permanent. Of the 72 unsuccessful pulses, 42 (58%) resulted in a transient accessory pathway block; the A-V interval and A/V ratio in these 42 pulses were statistically not different from the 30 pulses that had no effect at all. A significantly higher incidence of transient conduction block occurred in anterior compared with lateral accessory pathways (25 of 35 [71%] versus 16 of 34 [47%]; \( P<.05 \)).

Unsuccessful pulses in group A that resulted in transient conduction block were associated with a higher incidence of accessory pathway potential recordings (84% versus 53%; \( P<.05 \)) and were more frequently located in the anterior area (69% versus 42%; \( P<.05 \)), compared with unsuccessful pulses having no effect at all. The occurrence of transient accessory pathway block in the anterior area was associated with a shorter Δ-V interval than in the lateral area (4.3±7.0 versus 6.5±3.0 milliseconds, \( P<.01 \)).

In group B, transient accessory pathway block occurred in 8 of the 33 unsuccessful ventricular pulses (24%; \( P<.01 \) versus group A), and the mean time to block after a successful (atrial) pulse was, at 5.4±2.4 seconds, significantly longer than that after a successful (ventricular) pulse in group A (\( P<.05 \)). In analogy to group A, transient accessory pathway block was observed significantly more often in pulses delivered to the anterior region (6 of 6) than in pulses delivered to the lateral region (2 of 24; \( P<.01 \)).

Electrical power and pulse duration were higher and longer, respectively, in the anterior area (27.0±4.5 W and 25.8±10.3 seconds) than in the lateral area (24.2±3.8 W and 19.6±4.1 seconds; \( P<.05 \) for both parameters); a longer time to transient accessory pathway block was observed in the former area (7.7±5.6 versus 4.7±3.8 seconds; \( P<.05 \)).

Catheter Stability

The amplitudes of the local atrial and ventricular potential before and after pulse delivery were not statistically different in unsuccessful ventricular pulses in either group A or group B. At unsuccessful sites, the pre-A/post-A and the pre-V/post-V amplitude ratios
were 1.0±0.2 and 0.9±0.3, respectively, in pulses resulting in a transient accessory pathway conduction block, and 1.1±0.6 and 0.9±0.4, respectively, in those producing no effect. No differences in the pre-A/post-A and the pre-V/post-V amplitude ratios of unsuccessful pulses were found between group A (1.0±0.3 and 0.9±0.2, respectively) and group B (1.1±0.2 and 0.9±0.3, respectively). In group A, the pre-A/post-A ratio at successful sites was 1.2±0.6.

In 10 of 41 pulses that resulted in transient accessory pathway block, the electrogram could be evaluated during transient abolition of preexcitation. The local A/V ratio before current application (0.28±0.13) was markedly reduced during transient abolition of accessory pathway conduction (0.19±0.17; P<.05), but returned to the previous values once preexcitation recurred.

A significantly higher incidence of catheter displacements per patient was observed in the two cases composing subgroup A3 than in all other cases (5.5 versus 0.2; P<.001).

Discussion

Catheter ablation using RF current to interrupt accessory atrioventricular pathways has recently been established as a therapeutic modality that is associated with a success rate well in excess of 90%. However, accessory pathway ablation is usually not achieved in every patient with just a single RF current pulse applied to the atrioventricular annulus. Many accessory pathways, if not the majority, require multiple RF current applications before conduction block sets in. To date, all high-volume centers have reported the apparently common finding that some accessory pathways, including those on the left free wall, require for ablation a number of RF applications that is far in excess of the average. Thus, successful as well as unsuccessful RF pulses are encountered in the individual patient, and this observation prompted the question of whether local electrograms obtained from the distal electrodes of the ablation catheter can be used to predict the outcome of RF current delivery. Early studies in catheter ablation of accessory pathways have already pointed out that the direct recording of an accessory pathway activation potential precisely indicates the site of the accessory connection and that RF current application at such a site may abolish conduction through the pathway. However, accessory pathway potentials may also be recorded from sites at which subsequent current application is ineffective; conversely, successful RF pulses may not be associated with the recording of an accessory pathway potential. The possible reasons for this apparent discrepancy have not yet been addressed.

Four previous studies have systematically evaluated the relation between local electrograms and the effects of RF current to ablate accessory connections. Calkins et al found that in manifest pathways, independent predictors of outcome were the recording of a presumed accessory pathway potential, electrogram stability, and local ventricular activation occurring before the onset of the QRS complex. A 57% probability of success was reported when all three criteria were fulfilled. Chen et al found a similar probability of success (62%) when using a multivariate analysis that considered, next to the presence of an accessory pathway potential and a stable electrogram, an atrial activation potential >1 mV and a Δ-V interval <10 milliseconds. In the study by Silka et al, no information is given as to the location of manifest accessory pathways and the anatomic relation between the tip of the ablation catheter and the atrioventricular annulus at sites of current delivery. Furthermore, their analysis of preablation local electrograms is likely to be affected by the exclusion of unsuccessful pulses resulting in transient block. The reported positive predictive accuracy (81%) of the local A-V interval at a cutoff value of 50 milliseconds is not consistent with data from other authors and with the data from the present study. Bashir et al found that only the local Δ-V interval and the presence of a local accessory pathway potential were independent predictors of a successful outcome; the combination of a Δ-V interval ≤10 milliseconds and of an accessory pathway potential recording resulted in a positive predictive accuracy of 25%.

In the present study, a selected group of patients was treated with the intention to ablate the ventricular insertion of the accessory pathway. All patients had a single accessory pathway located on the left free wall, and the retrograde transaortic approach was chosen to wedge the ablation catheter for presumably best wall contact in the "pocket" beneath the mitral valve annulus. In contrast to previous studies, a markedly higher probability of success (87% positive predictive accuracy) could be demonstrated when the following four criteria were met: (1) the recording of a presumed accessory pathway potential, (2) a local atrial amplitude at least 1/10 of the local ventricular amplitude (A/V ratio ≥0.1), (3) an A-V interval ≤40 milliseconds, and (4) a local ventricular potential preceding or at least coinciding with the onset of the delta wave (Δ-V ≤0 milliseconds). All four conditions had an independent and statistically significant influence on the successful outcome of an RF current application to the ventricular insertion of the accessory pathway. Conversely, logistic regression showed that the electrogram condition Δ-V >10 milliseconds independently and with statistical significance singled out an unsuccessful ventricular pulse directed at an accessory pathway eventually ablated from the atrium. When this condition held in the presence of an A/V ratio >0.33, unsuccessful pulse delivery was predicted with a 82% probability.

The higher probability of success found in this study compared with previous studies may be explained by different criteria used for the electrogram analysis as well as by the patient (or rather accessory pathway) selection. Only manifest accessory pathways located on the left free wall were included in this study so as to obtain information from a homogeneous population. Because of the single-catheter technique, data obtained in this study refer only to antegrade conduction of accessory pathways.

Shortcomings of Local Electrogram Analysis

As long as a statistical analysis is applied to local electrogram parameters to guide RF current application for ablation, information will be insufficient if technical and, more importantly, biological (ie, anatomic) aspects are not taken into account. Disregard of these factors implies that the anatomy of the atrioventricular groove and the accessory pathway, the relation between the
ablation catheter and the anatomic substrate, and, finally, electrical parameters do not influence the outcome of an RF current pulse.

Previous studies have not addressed these issues.\(^9\) Successful RF current pulses that abolish accessory pathway conduction without a preceding (failed) pulse may not be regarded in the same manner as successful RF current pulses preceded by a certain number of failed pulses; therefore, the local electrograms recorded before the delivery of a successful pulse may differ. Multiple RF applications preceding a successful application are likely to have a cumulative effect, resulting in the success of the final application. It is therefore important to address the questions of whether there are differences between accessory pathways that can be ablated with just a single RF pulse and accessory pathways that can be ablated only with multiple RF pulses, and whether the local electrograms reflect these differences.

Factors Affecting the Outcome of RF Current Application

The specific factors that could influence the outcome of accessory pathway conduction of an RF pulse may be grouped into three categories. Anatomic factors include the accessory pathway, the atrioventricular groove, and the relation of the latter to atrial and ventricular myocardium. The anatomy of these components of cardiac morphology may differ with regard to the site along the atrioventricular groove, eg, for an anterior versus a posterior site. Moreover, an accessory pathway may insert into the ventricular myocardium subendocardially as well as subepicardially; it may have a perpendicular or an oblique course; and its ventricular insertion may consist of a single strand or a wide array of fibers.

Technical factors include primarily catheter placement relative to the accessory pathway insertion site. This is dependent not only on the anatomic situation outlined above but also on the manual skill of the investigator, who needs to place the ablation catheter in firm and stable contact with the mitral valve annulus. In the present study, catheter manipulation was performed exclusively by one investigator. Again, anatomic factors such as the papillary muscles or other anatomic obstacles within the targeted region may adversely affect this process.

Electrical factors relate to the actual delivery of RF current, and they include a sudden impedance rise with subsequent alteration of the cardiac tissues overlaying the accessory pathway and the insufficient transmission of electrical energy into the tissue at a potentially optimal site. For the present study, the temperature-controlled mode of RF energy delivery was not available.\(^18\)

Electrical factors will probably never be identified by the local electrogram because in both situations envisioned in the previous paragraph, the local electrogram could theoretically be "perfect" but RF application was still unsuccessful (false-positive electrogram). Conversely, anatomic and technical factors may be reflected at least partially in the local electrogram, particularly if a presumably uniform accessory pathway population is investigated. In contrast to previous studies, the present study included a selected group of patients. All had a single manifest accessory pathway located on the left free wall, and ablation attempts were initially directed at the ventricular insertion of the pathway. Only in cases of failure was the ablation catheter advanced toward the atrial accessory pathway insertion.

General Findings

Catheter stability in this study was ensured by unchanged local atrial (and, only for unsuccessful pulses, ventricular) amplitudes before and after RF current application. In previous studies, catheter stability was judged only from preablation electrograms. Therefore, those authors would have missed a minor catheter displacement during RF current delivery, which would associate a "perfect" electrogram with an unsuccessful pulse.

Ablation at the ventricular insertion was achieved in exactly one half of the 52 patients with the first RF current pulse. These patients were differentiated throughout the study from those constituting almost the other half, in whom a median of 3 (maximum 6) pulses preceded the successful pulse. The anatomic distribution of accessory pathways in these two groups was not different. Two remaining patients required an unusually high number of ventricular pulses (11 and 12, respectively) for ablation, and both had an anteriorly located accessory pathway. The anatomic distribution of the 10 accessory pathways eventually ablated from the atrium followed the same pattern as those ablated from the ventricle; about 30% were located anteriorly, 60% laterally, and 10% posteriorly.

Relation of Accessory Pathway and Atrioventricular Groove: Anatomic Characteristics

When ablation was achieved with a single RF current pulse, as was the case in 26 patients, the local electrogram parameters were likely to reflect an "optimal" set of accessory atrioventricular connections with a presumably subendocardial course and/or a locally circumscript ventricular insertion as well as a close and stable contact of the ablating catheter with the mitral valve annulus. These accessory pathways did not show an anatomic predilection; they were found in all regions along the left free wall, with a distribution reflecting the general distribution of left-sided accessory pathways.

The electrogram characteristics of successful pulses in this "optimal" group of accessory pathways were not different from the electrogram characteristics of the successful pulses that were preceded by a varying number of unsuccessful pulses. Unsuccessful pulses were associated with a lower but still high incidence of accessory pathway potential recordings but also with generally longer local A-V and Δ-V intervals compared with the successful pulses. These findings suggest that a wider ventricular insertion (rather than a subepicardial course) may have been present in this group of accessory pathways, and that cumulative energy, possibly associated with an increase in lesion size, may have accounted for the eventual ablation. Poor catheter contact below the mitral annulus as an alternative explanation for unsuccessful attempts appears to be unlikely, because no differences were found between the A/V ratios of successful versus unsuccessful pulses and, the pre-A/post-A amplitude ratios at unsuccessful sites did not differ from those at successful sites.
In addition to the presence of an accessory pathway potential recording, a specific accessory pathway potential morphology ("Zorro" potential) was found in the vast majority of local electrograms recorded along the left free wall.

**Anterior Versus Lateral/Posterior Accessory Pathways**

Two patients required more than 10 ventricular pulses for eventual ablation of an accessory connection located anteriorly. The low A/V ratios found for unsuccessful as well as successful RF current pulses in these patients probably suggest an unusual anatomy of the anterior atrioventricular region. It may not be possible in this region to position the catheter tip close enough to the ventricular insertion of the accessory pathway because of the anterior mitral leaflet covering the endocardial surface of the summit of the ventricular wall where it joins the annulus. This hypothesis is supported by the high incidence of transient accessory pathway block encountered in both patients. Compared with the lateral and posterior regions, a higher incidence of transient accessory pathway block was generally observed for all pathways located anteriorly. Also, in the anterior region, higher amounts of electrical energy resulted in a longer time to accessory pathway block than in the lateral region. Generally, conduction block occurring later than 13 seconds never resulted in permanent accessory pathway interruption, which is indicative of too large a distance between the catheter tip and the target.\(^{18}\) The "adverse" anatomy of the anterior region is further supported by the higher incidence of catheter displacements among "potentially successful" pulses, compared with the lateral region. The increase in the A-V and, most notably, the ∆-V interval of successful pulses in the anterior compared with the lateral and posterior areas suggests that a more epicardial or a more oblique course of these pathways may also play a role.

**Ablation at the Atrium**

Accessory connections that were eventually ablated from the atrial aspect of the mitral annulus provide only indirect information as to their anatomic characteristics. The distribution along the atrioventricular annulus of these pathways was consistent with the general distribution of left-sided accessory pathways. Unsuccessful pulses delivered to the ventricular insertion of these pathways (before the advancement of the catheter to the atrial insertion) differed most notably from unsuccessful pulses applied to accessory pathways eventually ablated at the ventricular insertion in the local ∆-V interval, which was significantly longer and exclusively positive in the former (it exceeded 10 milliseconds in more than half the pulses). Also, a longer A-V interval was usually recorded in the former. Thus, in accessory pathways that required ablation at their atrial insertion, the local ventricular electrogram was consistently recorded after the onset of the delta wave had been inscribed on the surface ECG. This may indicate a more epicardial course of these pathways and of the ventricular insertion in particular. Ablation from an atrial catheter position in the same anatomic region as that of failed ventricular pulses supports this interpretation. Further evidence is given by the significantly lower incidence of pulses resulting in transient accessory pathway block (24% versus 58% in accessory pathways ablated at the ventricular insertion) and by the longer local A-V interval recorded at the ventricular site in these patients compared with those successfully approached at the ventricular insertion.

Inadequate catheter positioning and poor catheter contact below the mitral annulus appear to be unlikely alternative explanations in this subset of accessory pathways, because several attempts at optimal catheter positioning were made and an A/V ratio >0.33 was achieved in the majority of cases; moreover, adequate catheter contact was verified by the absence of differences in the preapplication and postapplication atrial and ventricular amplitudes.

**Limitations of Anatomic Inferences Drawn From Local Electrograms**

When the local A/V ratio is regarded as a marker for the relation between the catheter electrode and the atrioventricular groove, the interpatient variability between atrial and ventricular myocardium at the atrioventricular ring is not taken into account. The larger the extent of atrial tissue at the atrioventricular groove, the higher the A/V ratio, regardless of catheter electrode positioning. The relative extent of such relations cannot be assessed by local electrogram analysis in the individual patient. Similar considerations are true for local conduction intervals. The interaction of the relative timing and the direction of the preexcited wave front with differential recording sources (namely, the endocardial electrode and the surface ECG recording electrodes) may influence local electrogram parameters. These factors may also account for a successful RF pulse in the absence of an accessory pathway potential recording.

Because of the nonavailability of temperature-controlled RF current delivery, the potential influence of temperature at the electrode/tissue interface on local electrogram parameters could not be assessed. A high electrode/tissue interface temperature presumably reflects good wall contact.\(^{18}\) Compared with other locations in the heart, catheter positioning beneath the mitral valve provides better wall contact\(^ {19}\) and, therefore, wide variations in electrode/tissue interface temperature are not likely to occur. Moreover, catheter stability in the present study was ensured by a systematic comparison of preapplication and postapplication local atrial and ventricular deflections.

In this study, a multivariate logistic regression analysis was applied assuming each RF pulse to be an independent event with no influence of the antecedent pulse. Because an unsuccessful pulse might affect the outcome of a subsequent pulse, as observed in patients of subgroup A2, the applicability of the logistic regression may be limited. In addition, inferences drawn by comparisons among subgroups may be limited by the relatively small numbers.

Compared with the standard multiple-catheter approach, definitions of the mitral annulus and the overall pattern of antegrade and retrograde activation along the annulus are not possible with the single-catheter technique. The presence of a coronary sinus catheter would help to validate the inferences drawn in this study.
about the anatomic characteristics of the accessory pathway course.

**Clinical Relevance**

The stepwise approach, guided by local electrogram analysis, to catheter positioning for ablation of manifest left-sided accessory pathways at the ventricular insertion needs to be confirmed in a prospective study. The incidence of left free-wall accessory pathways in which the four criteria outlined in this study can be met is not known, and neither is the success rate that would follow such an approach. A major limitation of this approach appears to be the high number (50%; Table 4) of successful ventricular pulses that did not meet all four criteria. Because of the complexity of an ablative attempt and the inherent number of factors possibly influencing the outcome of an RF pulse, no definitive clues were found in this retrospective study that distinguished successful from unsuccessful pulses.

When a ventricular approach is selected to ablate left free-wall accessory pathways, a successful pulse is in most cases delivered within a range of one to six attempts at a site with similar electrogram features. A cumulative effect of energy delivered to the same area may promote a successful outcome. In cases of an A/V ratio <0.1 and a Δ-V interval >10 milliseconds, a search for a better position at the ventricular aspect of the mitral annulus appears advisable: a better A/V ratio was invariably found in all but two successful attempts and a Δ-V interval ≤10 milliseconds in 73% of cases. In cases where a Δ-V interval >10 milliseconds cannot be improved upon by catheter manipulation, despite an apparently close contact of the catheter tip with the mitral annulus as reflected by an A/V ratio >0.33, ablation of the accessory pathway should be attempted at its atrial insertion.

**Conclusions**

The systematic analysis of endocardial recordings with respect to the outcome of RF current application presented in this study of manifest accessory pathways located on the left free wall provides insights into the interrelations of current delivery and accessory pathway location and geometry, atrioventricular groove anatomic, and catheter orientation. The vast majority of left free-wall accessory pathways, whether located anteriorly, laterally, or posteriorly, appear to have a rather circumscript ventricular insertion and a partially endocardial course, and they bridge the mitral annulus at sites that permit close contact with the ablating catheter.

Ablation of these pathways can be expected with a few pulses delivered from a catheter position at the ventricular aspect of the mitral valve annulus, provided that the pathway is precisely located via local electrogram criteria. Exceptions are probably represented by pathways with an epicardial course or a wide ventricular insertion, and by pathways embedded in an “adverse” anatomy of the atrioventricular groove that may prevent close enough contact with the ablating catheter. Consistent inability to record a Δ-V interval of <10 milliseconds probably points to a more epicardial ventricular insertion of the pathway, which may then be ablated at its atrial insertion. Repeated occurrence of transient accessory pathway block despite catheter manipulation for an “optimal” ablation site in the same area may indicate a branched ventricular insertion (or a subepicardial course), and ablation using the ventricular approach is likely to be achieved with successive applications of RF current. The usefulness of an atrial approach in this setting needs to be established. A local A/V ratio of <0.1 invariably indicates poor contact of the ablating catheter with the mitral annulus, regardless of the values of all other electrogram parameters.

The logistic regression analysis performed in this study using readily verifiable electrogram conditions predicted (1) an anatomic location of the accessory pathway within the boundary of the RF current-induced lesion and (2) repeatedly unsuccessful attempts to ablate the ventricular accessory pathway insertion. This type of analysis may help to minimize the number of ineffective RF pulses in patients undergoing catheter ablation of an accessory pathway.

The concepts introduced in this study appear to be potentially useful in any ablation attempt directed at the ventricular insertion of a left free-wall accessory pathway, regardless of the number of catheters used. It remains to be determined whether they are applicable to accessory pathways that can be ablated only from other than ventricular catheter locations, including those in the posteroseptal space and on the right side of the heart.

**References**

11. Silka MJ, Kron J, Halperin BD, Griffith K, Cramb B, Oliver RP, Walence CG, McAnulty JH. Analysis of local electrogram charac-


Anatomic, electrical, and mechanical factors affecting bipolar endocardial electrograms. Impact on catheter ablation of manifest left free-wall accessory pathways.

R Cappato, M Schlüter, L Mont and K H Kuck

Circulation. 1994;90:884-894
doi: 10.1161/01.CIR.90.2.884

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1994 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/90/2/884

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org/subscriptions/