New Algorithm for the Localization of Accessory Atrioventricular
Connections Using a Baseline Electrocardiogram

ADAM P. FITZPATRICK, MD, MRCP, ROLANDO P. GONZALES, MD,
MICHAEL D. LESH, MD, FACC, GUNNARD W. MODIN, BS, RANDALL J. LEE, MD,
MELVIN M. SCHEINMAN, MD, FACC
San Francisco, California

Objectives. In this study, we propose a new algorithm for accessory atrioventricular pathway localization using a 12-lead electrocardiogram (ECG).

Background. Radiofrequency catheter ablation produces a very discrete lesion, and ECG localization based on surgical dissection is obsolete.

Methods. Stepwise discriminant analysis was used to assess the relation of 18 pre-excited ECG (QRS duration >100 ms) variables to the site of successful ablation in 93 patients. The most discriminating variables were combined to form rules for each location. The ECGs were retested by these rules to determine predictive accuracy.

Results. If the precordial QRS transition was at or before lead V1, the pathway had been ablated on the left side. If it was after lead V2, the pathway had been ablated on the right side. If the QRS transition was between leads V1 and V2 or at lead V2, then if the R wave amplitude in lead I was greater than the S wave by ≥1.0 mV, it was right-sided; otherwise, it was left-sided (p < 0.0001, sensitivity 100%, specificity 97%). Right-sided pathways. If the QRS transition was between leads V3 and V4, the pathway was right septal; if after lead V4, it was right lateral. If it was between leads V3 and V4, then if the delta wave amplitude in lead II was ≥1.0 mV, it was right anteroseptal; otherwise, it was right lateral (p < 0.0001, sensitivity 97%, specificity 95%). In right lateral locations, if the delta wave frontal axis was ≥0°, or if it was <0° but the R wave amplitude in lead III was ≥0 mV, it was anterolateral; otherwise, it was posterolateral (p < 0.0001, sensitivity 100%, specificity 87.3%). Anteroseptal pathways had two or more positive delta waves in leads II, III and aVF (p < 0.0001, sensitivity 100%, specificity 100%). Posteroseptal pathways (two or more negative inferior lead delta waves) were less well discriminated from right midseptal pathways (inferior delta wave sum ≤2≤1—1) (p < 0.0001, sensitivity 76.5%, specificity 71%). Left-sided pathways. Two or more positive delta waves in the inferior leads or the presence of an S wave amplitude in lead aVL greater than the R wave, or both, discriminated left anterolateral pathways from posterior pathways (p < 0.001, sensitivity and specificity 100%). If the R wave in lead I was greater than the S wave by ≥0.8 mV, and the sum of inferior delta wave polarities was negative, the location was posteroseptal; otherwise, it was posterolateral (p < 0.05, sensitivity 71.4%, specificity 100%).

Conclusions. Using the algorithm derived, a right-sided accessory pathway can be reliably distinguished from one that is left-sided, right free wall from right septal, right anterolateral from posterolateral and anteroseptal from other right septal pathways. Left anterolateral pathways can be distinguished from left posterior pathways and left posterolateral pathways from left posteroseptal pathways.

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Radiofrequency techniques for catheter ablation of accessory atrioventricular (AV) connections demand precise pathway location because of small lesion size (1-3). Data from previous studies in which surgical ablation was correlated with surface electrocardiographic (ECG) characteristics therefore require revision. This is particularly true for septal locations in view of the extensive dissection required for surgical ablation of these pathways.

A reliable method of noninvasive pathway localization might help direct invasive mapping and advance planning of special techniques (e.g., transseptal puncture, right coronary mapping). The shortcomings of existing methods based on surgical ablation have been highlighted elsewhere (4,5) and argue for the use of a much more sophisticated statistical technique evaluating many more ECG variables.

The specific aims of this study were to reappraise the predictive value of the baseline 12-lead surface ECG (as opposed to an ECG recorded during maximal pre-excitation with atrial pacing [6]) as a noninvasive tool for differentiation of pathway locations in the era of radiofrequency catheter ablation. We planned to use a stepwise discriminant statis-
tical analysis, and by this approach we hoped to improve the poor sensitivity and specificity shown with other schemes (5). The final goal was to produce a compact flowchart for reference while interpreting baseline ECGs.

**Methods**

**Patients.** Between August 1990 and August 1992, 180 patients with accessory pathway-mediated tachycardia underwent radiofrequency catheter ablation of accessory pathways that was successful in 164 (91%). Of these 180 patients, 97 had manifest pre-excitation on a baseline 12-lead ECG that prolonged the QRS duration above the upper limit of normal, (100 ms). Sixty-seven patients without such pre-excitation and four patients with multiple pathways were excluded from the analysis. Ninety-three patients (56 male, mean age 32 ± 19 years) with manifest pre-excitation and successful radiofrequency catheter ablation formed the study group.

**Electrophysiologic study.** Each patient underwent initial invasive electrophysiologic study (3) under mild sedation in the postabsorptive state after giving informed, written consent. With the use of femoral and internal jugular venous access, quadrupolar electrode catheters were positioned against the high right atrium, the low septal right atrium (0.5-cm electrode spacing), the coronary sinus (1-cm electrode spacing) and the right ventricular apex. The quadrupolar catheter placed in the low septal right atrium was positioned to record the His bundle electrogram, and three channels were displayed representing bipolar recordings from electrodes 1 + 2, 2 + 3 and 3 + 4. The catheter was positioned so as to obtain, approximately, a 1:1 ratio of atrial/ventricular electrograms on one of these channels. Surface leads I, II, aVF and V1 were also monitored. Bipolar intracardiac electrograms were filtered with a bandpass of 30 to 250 Hz. The presence and location of the accessory pathway were determined, as well as the involvement of the accessory pathway in tachycardia using previously described methods (7). After initial electrophysiologic evaluation had determined the approximate location of the accessory pathway, a tip-deflecting 7F ablation catheter with a large (4 to 5 mm) distal electrode (Mansfield Scientific, Inc. or EP Technologies) was placed along the tricuspid or mitral annulus. For left-sided accessory pathways, the putative site of the accessory pathway was determined by mapping in the coronary sinus. Either a transarterial ablation catheter was manipulated on the ventricular side of the mitral valve apparatus using the coronary sinus electrode as a target, or a transseptal puncture was performed (8) to access the mitral annulus on the left atrial side. A transvenous approach was used for right septal and right lateral pathways. Ablation was attempted at sites from which the following were recorded: 1) the shortest time from the onset of ventricular activation to local atrial activation during orthodromic reciprocating tachycardia; 2) an atrial deflection of at least 0.4 mV for left-sided pathways and 1.0 mV for right-sided or septal pathways; 3) fusion of the local atrial and ventricular deflections during pre-excited complexes (sinus rhythm or atrial pacing); and 4) the local ventricular deflection occurring before or just at the onset of the delta wave on the body surface. In addition, we required 5) fluoroscopic evidence of concordant movement of the ablation catheter with the plane of the mitral or tricuspid annulus. We did not attempt to prove that we were recording accessory pathway potentials (1), but electrograms from sites meeting these requirements were usually polyphasic and continuous, and such potentials may therefore have been present. Once positioned, 15 to 35 W of continuous, unmodulated current at 330 to 550 kHz was delivered between the distal pole of the ablation catheter and a large surface area skin patch placed over the left scapula with the use of a radiofrequency generator (Radionics or EP Technologies). Energy was delivered for up to 100 s at a given location but was usually discontinued after 15 to 20 s if no electrophysiologic effect (loss of pre-excitation) was observed. If accessory pathway conduction was still present, the catheter was repositioned and the procedure repeated.

**Accessory pathway locations (see Fig. 1).** For analysis of pathways ablated on the left versus the right side of the heart, ECG characteristics of all manifest pathways on each side were considered together. Pathways ablated on the right side of the heart were localized to five regions around the tricuspid annulus and left-sided pathways to three regions around the mitral valve annulus.
Right sided pathways. Anteroseptal. This area was demarcated fluoroscopically as being at or just cephalad to the bipolar on the low septal right atrial catheter recording approximately equal atrial and ventricular electrograms and a satisfactory His bundle electrogram, on the tricuspid annulus in a 45° right anterior oblique projection (the annulus being radiologically distinguished by the visible epicardial fat in the external AV groove). The ablation catheter was confirmed to be against the septal AV annulus in the best left anterior oblique projection for visualizing the tricuspid annulus en face (usually 40°), recording atrial and ventricular electrograms, as detailed previously. The lateral extremity of this location was the most cephalad point of the tricuspid valve ring abutting the septum. Midseptal. This location was identified in a 45° right anterior oblique projection at the tricuspid annulus between the electrode catheter recording the His bundle electrogram and that marking the coronary sinus os. Right posteroseptal. Pathways in this location were defined in a 45° right anterior oblique projection as being (peri os) inferior or posterior to the coronary sinus os as far as the caudal extremity of the tricuspid annulus. Successful ablation catheter tip positions in this location were seen to be abutting the septum in the left anterior oblique projection. Posterolateral. This location was defined in the 45° left anterior oblique projection extending from the right posteroseptal location at the caudal extremity of the tricuspid annulus to the midpoint of the annulus on the right ventricular free wall. Anterolateral. This was an area between the limit of the anteroseptal location, extending to the midpoint of the right free wall or superior extremity of the posterolateral location.

Left sided pathways. Left posteroseptal. Pathways ablated in this location were within 1 to 1.5 cm of the os of the coronary sinus, indicated by the fluoroscopic position of the poles of the electrode in the coronary sinus and angiographic localization of the coronary sinus os by contrast injection through the electrode catheter lumen, which was routinely performed during coronary sinus catheter positioning. Left posterolateral. This extended from the left posteroseptal location to the midpoint of the mitral annulus at the left free wall (an approximately 3 o’clock position on the mitral annulus viewed in the left anterior oblique projection). Left anterolateral. This extended from the midpoint of the mitral annulus to the left fibrous trigone marked by the edge of the aortic root.

Electrocardiographic analysis. Twelve-lead ECGs were available for all patients, and the most pre-excited baseline ECG available was used for analysis. The following ECG variables were used in this study in the qualitative assessment of the effect of pre-excitation of different pathway locations and were subjected to stepwise linear discriminant analysis: 1) delta wave amplitude (mV) in leads I, II and III; 2) the sum of the polarities of the delta waves in inferior leads II, III and aVF (+1 for positive, 0 for isoelectric, -1 for negative); 3) delta wave polarity in lead V1; 4) delta wave frontal plane axis (degrees); 5) delta wave frontal vector magnitude (mV); 6) R wave amplitude in leads I, II and III (mV); 7) QRS frontal plane axis (degrees); 8) R wave amplitude in V1 (mV); 9) S wave amplitude in V1 (mV); 10) R wave amplitude minus S wave in V1 (to determine the dominant deflection); 11) QRS transition zone chest lead (see Fig. 2); 12) relative amplitude (mV) of the R versus S wave in lead aVL; 13) relative amplitude (mV) of the R versus S wave in lead I; and 14) QRS duration (ms).

The delta wave frontal plane vector was calculated by measurement of the height of the delta wave in the 1st 40 ms of the QRS complex in standard leads, as previously described (6). Delta wave polarity was determined according to the scheme illustrated in Figure 3. An isoelectric delta wave (Fig. 3C) followed the criteria of Lemery et al. (4), that is, if the 1st 40 ms of the QRS complex at the time of pre-excitation in another simultaneous lead remained on the baseline or was deflected from the baseline but returned to the baseline before the onset of the R wave, or if the entire 40-ms segment was on the baseline. If the delta wave duration was <40 ms, the height of the delta wave was determined from the point at which it joined the main QRS deflection. The horizontal plane QRS axis was estimated from numeric scoring of the zone of the QRS transition, as shown in Figure 2. If the R wave was dominant in lead V1, transition was scored as zero. If the R and S waves were equiphasic in any lead, then that lead was the transition lead, and if the QRS transition was between two leads, a half score was allotted (e.g., V2.5 for the QRS transition between leads V2 and V3).

Statistical analysis. Initially the statistical significance of all variables was tested with univariate analysis, one way analysis of variance for continuous variables, and the chi-square test for categoric data. Post hoc tests were the Scheffé test for the analysis of variance and the Bonferroni...
test for the chi-square test. Results are expressed as mean value ± SD, and a p value <0.05 was considered significant. All ECG characteristics were then reanalyzed in a stepwise linear discriminant analysis. The statistical level for a variable to enter the model was set at p < 0.05, and the statistical level for a variable to be removed from the model was set at p > 0.10. To estimate the probability of misclassification, a jackknife classification matrix was generated. Six linear discriminant analyses (8) were performed between groups identified by the site of radiofrequency catheter ablation: 1) right side versus left side; 2) right free wall versus right septum; 3) right anterolateral versus right posterolateral; 4) right anterior septum versus right midseptum versus right posterior septum; 5) left anterolateral versus left posterior; 6) left posteroseptal versus left posterolateral. To increase discrimination between locations, the most significantly different variables were then combined to construct rules for identifying each location. Finally, each ECG was reanalyzed according to these rules to determine sensitivity, specificity and predictive accuracy. The Student unpaired t test was used to compare QRS duration between locations.

Results

Pathway locations. Of the 93 pathways, 56 were right sided, and 37 were left sided (Fig. 1). The mean QRS duration in right-sided pathways was significantly greater than in left-sided pathways $145 \pm 17$ ms [range 100 to 180] vs. $131 \pm 15$ ms [range 110 to 164], $p < 0.001$. Eleven pathways were right anterosperosal (mean QRS duration $151 \pm 19$ ms); 7 were right midseptal ($143 \pm 19$ ms), 17 were right posteroseptal ($138 \pm 22$ ms); 9 were right posterolateral ($150 \pm 17$ ms); and 12 were right anterolateral ($147 \pm 13$ ms). Five pathways were left posteroseptal ($131 \pm 12$ ms); 13 were left posterolateral free wall ($133 \pm 16$ ms); and 19 were left anterior free wall ($129 \pm 12$ ms) (Fig. 1).

Stepwise discriminant analysis for all ECG characteristics (Table 1). Right versus left-sided pathways. The most significant variable was the QRS transition ($p < 0.0001$), or, if this was equivocal, the R/S wave amplitude ratio in lead I ($p < 0.0001$). If the QRS transition was at or before lead V1 (i.e., there was an equiphasic QRS complex or dominant R wave in lead V1), then it was left-sided, and if the QRS transition was after lead V2, then it was right-sided. If the QRS transition was between leads V1 and V2 or at lead V2, and the R wave amplitude in lead I was greater than the S wave by $\geq 1.0$ mV, then it was right-sided; otherwise, it was left-sided (sensitivity 100%, specificity 97%, positive predictive value 98%, negative predictive value 100%). This combination discriminated 99% of pathways, with one left posteroseptal pathway misclassified as right-sided.

Right septal versus right free wall. The QRS transition ($p < 0.0001$) was found to be the most significant variable, and the delta wave amplitude in lead II ($p < 0.005$) assisted discrimination if the first variable was equivocal. The QRS transition at or before lead V3 indicated a septal location, and the QRS transition at or after lead V4 indicated a lateral location. Where the QRS transition was between leads V3 and V4, then a delta wave in lead II $\geq 1.0$ mV indicated a septal location, and $<1.0$ mV indicated a lateral location (sensitivity 97%, specificity 93%, positive predictive value 97%, negative predictive value 95%). One anterosperosal pathway was misclassified as right lateral, and one anterolateral pathway was misclassified as septal.
Table 1.

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<th>Correct</th>
<th>%</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPAP%</th>
<th>NPAP%</th>
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<td>Precordial QRS: +</td>
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<td>100</td>
<td>97</td>
<td>93</td>
<td>100</td>
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<td>100</td>
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<td>D frontal axis +</td>
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<td>100</td>
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L = left sided; No. Correct/Incorrect = number of pathways correctly localized by the algorithm; NPAP = predictive accuracy of a negative test; PPAP = predictive accuracy of a positive test; QRS: = horizontal plane QRS transition lead; R/S ratio = R wave amplitude ratio; $\Sigma$ polarity = sum of delta wave polarities.

**Right anterior versus right posterior free wall locations.** The delta wave frontal plane axis was found to be the most significant variable ($p < 0.0001$). If this was equivocal, the R wave amplitude in lead III ($p < 0.0005$) was used. If the delta wave frontal plane axis was $\geq 0^\circ$, then the pathway location was anteroseptal. If it was less than $-1^\circ$, it was posterior. If it was equal to $-0.5$ or $0$, then it was midseptal. All 11 anteroseptal pathways were correctly classified (sensitivity 87.3%, specificity 100%, positive predictive value 100%, negative predictive value 90%). One anteroseptal pathway was misclassified as posteroseptal.

**Anteroseptal versus midseptal versus right posteroseptal locations.** The sum of the delta wave polarities in inferior leads II, III, and aVF was found to be the most significant variable ($p < 0.0001$). If this sum was greater than $+1$, the pathway was anteroseptal. If it was less than $-1$, it was posterior. If it was equal to $-0.5$ or $0$, then it was midseptal. All 11 anteroseptal pathways were correctly classified (sensitivity 100%, specificity 100%). Sensitivity for discrimination of right posteroseptal from right midseptal pathways was 76.5%, specificity 71%, positive predictive value 87% and negative predictive value 55.5%. Thirteen of 17 right posteroseptal pathways were correctly located, with 4 misclassified as midseptal. Two of seven midseptal pathways were misclassified as posteroseptal. Figure 4 shows a posteroseptal pathway ablated on the right side of the heart that was misclassified as midseptal (septal location was indicated by the QRS transition between leads V2 and V3). Figure 5 is an ECG example of a right anteroseptal pathway that was misclassified as right anterolateral. An ECG example of a correctly located right posteroseptal pathway is given in Figure 6, and Figure 7 is an example of a correctly located right midseptal pathway.

**Left anterolateral versus left posterior locations.** The most significant variables were the sum of delta wave polarities in the inferior leads ($p < 0.0001$) and the R/S wave amplitude ratio in lead aVL ($p < 0.001$). The finding of two or more positive delta waves in the inferior leads indicated an anterior location, as did the presence of a larger amplitude S than R wave in lead aVL (sensitivity 100%, specificity 100%, positive predictive value 100%, negative predictive value 100%). Figure 8 shows a correctly identified left anterolateral pathway.

**Left posteroseptal versus left posterolateral.** The most significant variable was the sum of the inferior delta wave polarities ($p < 0.05$), and the R/S wave amplitude ratio in lead I ($p < 0.05$) was useful. If the R wave in lead I was greater than the S wave by $\geq 0.8$ mV, and the sum of inferior delta wave polarities was negative, the location was posteroseptal; otherwise, it was left posterolateral ($p < 0.05$) (sensitivity 71.4%, specificity 100%, positive predictive value 100%, negative predictive value 77%). Figure 9 shows a flowchart constructed from the discriminant analysis.

**Discussion**

To derive a clinical algorithm for accessory pathway localization, we subjected baseline 12-lead ECG variables commonly used by experienced electrophysiologists to stepwise discriminant analysis in patients with pre-excitation causing abnormal QRS prolongation. For most locations we showed a much higher sensitivity, specificity and predictive value than other available methods (5). This approach should allow rapid assessment of accessory pathway location by following the logic of a simple flowchart. We also highlighted the limitations of the baseline ECG for distinguishing be-
between right posteroseptal and midseptal pathways and left posteroseptal and left posterolateral pathways.

Limitations of existing methods. The limitations of existing methods of ECG analysis have been highlighted by Yuan et al. (5). Gallagher et al. (6) based their analysis on surgical ablation in 163 patients and identified 10 locations around the tricuspid and mitral annuli and the septum (6). Yuan et al. (5) found that it was necessary to reduce the 10 locations to 4 (right free wall, left free wall, anteroseptal and posteroseptal) to use the scheme to evaluate their own 182 surgical patients. By this method they were able to increase sensitivity from 57% to 88.5% and to roughly maintain specificity (65.9% vs. 69.4%). However, Lemery et al. (4) were able to show concordance of the ECG with each of the original 10 surgical sites in only 32% of their series of 47 patients using the Gallagher criteria. In addition, the ECGs interpreted in the Duke experience were not baseline recordings but were recorded during atrial pacing (6).

Milstein et al. (9) reported the only available algorithmic approach to the problem, with four locations (right free wall, left free wall, posteroseptal and anteroseptal) around the annulus but, again, based on incomplete (97 of 141) surgical ablation. There were several limitations to Milstein et al.'s (9) method, although it was the most favorably reviewed in Yuan et al.'s (5) analysis of available schemes. Posteroseptal pathways were classified as one group, rather than as right and left sided or midseptal and posteroseptal pathways. The algorithm was constructed by taking ECG variables and then
deriving a location. Some locations could therefore appear twice in the algorithm, making it difficult to use. As assessed by Yuan et al. (5) Milstein et al.'s (9) algorithm carried a 71% sensitivity and 91% specificity. These studies all used surgery as the reference standard, and the extent of surgical dissection along the right or left annulus precluded pinpoint correlation with ECG findings. Furthermore, surgical ablation of pathways in the septum below the His bundle would involve extensive dissection of the posteroseptal space. In contrast, radiofrequency catheter ablation demands an anatomically distinct midseptal location and much greater precision in localization because of small lesion size. In our study we took the known location of successful catheter ablation and identified the best characteristics for discrimi-

Figure 6. Twelve-lead electrocardiogram in a patient with a correctly localized right posterolateral accessory pathway. The QRS transition is between leads V3 and V5, indicating a right-sided pathway. The delta wave in lead II was -0.2 mV, indicating a free wall pathway. The delta wave axis was -58°, and there was no R wave in lead III, correctly locating a right posterolateral pathway.

nating pathways in these locations from all other pathways in the study group of 93 pre-excited ECGs. We then combined variables to improve discrimination and developed rules for each location. Finally, we expressed the predictive accuracy of the localization in terms of the number of pathways correctly and incorrectly located by these rules. Sequences of logic were then produced, with each location appearing only once at the end of each sequence, and all locations were combined in a single flowchart.

Some of the most useful ECG variables in the analysis were unconventional, being based on QRS complex appearance rather than solely on delta wave variables. Left-sided pathways would be expected to show early horizontal precordial transition, as noted by Rosenbaum et al. (10) in their

Figure 7. Twelve-lead electrocardiogram in a patient with a correctly localized right midseptal accessory pathway. The QRS transition was between leads V1 and V2, and the R wave amplitude in lead I (2.1 mV) was far greater than the S wave (0.01 mV), indicating a right-sided pathway on the septum. The inferior lead delta wave polarities were II positive, III isoelectric and aVF isoelectric (i.e., a sum of +1), indicating a right midseptal location.
early classification of type A and B pre-excitation. However, the weakness of Rosenbaum et al.’s criteria was that although type A was very specific for left-sided locations, type B could occur at either septal or right free wall sites. In our criteria, where the zone of transition alone did not differentiate, we were able to show that the additional influence of site of ventricular insertion on R/S wave amplitude ratio in lead I, and therefore ventricular depolarization toward or away from the left side, did discriminate. We explain these findings on the basis that early activation of the right septum or right free wall would result in earlier activation of the right ventricle and later activation of the left ventricle via the normal His-Purkinje route. This pattern would be expected to be manifest as a left bundle branch block and explains the dominant R wave observed in lead V1 as well as the rS or qs patterns in lead VI. The latter findings explain the later transition observed for right septal and free wall pathways compared with left free wall pathways. Left free wall pathways produce a right bundle branch block pattern by earlier activation of the left ventricle. Left anterolateral pathways were characterized by a large S wave in lead I, reflecting early activation of part of the left ventricle away from the left side as well as early transition in the precordial leads.

We also found that right septal and right lateral pathways could be distinguished on the basis of the QRS transition and the amplitude of the delta wave polarity in lead II. Because the plane of the tricuspid annulus lies anterior and inferior to the interventricular septum, the resultant spatial vector from right free wall pathways would be expected to result in later horizontal transition (posteriorly directed vector) and a more superior delta wave compared with septal activation. Moreover, we found that right free wall pathways could be best separated by the delta wave frontal axis. Pre-excitation from right posterolateral pathways (because of their inferior location on the annulus) would be expected to show a more superior frontal plane delta wave axis compared with right anterolateral pathways. There was also a clear influence of fusion of pre-excited ventricular myocardium with normally excited myocardium on the resultant QRS frontal axis because the presence or absence of an R wave in lead III helped to discriminate anterior from posterolateral pathways, even when the delta wave axis alone was equivocal. Furthermore, in the chest leads, QRS transition was discriminant in determining location, removing the need to calculate delta wave horizontal plane axis.

Right anteroseptal pathways were clearly distinguished from other right septal pathways because the superior location of these connections resulted in an inferior frontal plane QRS vector with positive delta waves in at least two of the three inferior leads. Posteroseptal and midseptal pathways that could be ablated from the right side were less well separated by the sum of inferior delta wave polarities. Both locations are inferior to the His bundle, and pre-excitation of the septum would tend to direct the delta wave cephalad and to the left, accounting for the lesser discrimination between these locations, highlighting the limitations of the baseline scalar ECG.

Limitations of the study. We defined five right-sided and three left-sided locations on the basis of available fluoroscopic landmarks and attempted to remove ambiguity as to the site of transition between adjacent locations. However, arbitrary division of the annuli may introduce unavoidable error in distinguishing between locations. An example of this would be a pathway located just lateral to the right anteroseptal location that might have rather different characteristics than one located just cephalad to the right posterolateral free wall location, although both would be classified as right anterolateral. Similarly, we made an arbitrary division of the right septum below the His bundle catheter into midseptal and posteroseptal, which may lead to overlap.
However, overall there were few misclassifications, and predictive accuracy was very high.

The analysis depended on evaluation of the most pre-excited baseline ECG available, and there was, consequently, a wide range of QRS duration. Atrial pacing or adenosine infusion would have retarded anterograde conduction via the AV node, enhancing pre-excitation, particularly in left free wall locations. However, we wanted to assess the noninvasive value of the scalar ECG. Some investigators have suggested that a QRS duration of 140 ms is necessary for accurate localization (6). This analysis indicates that pathways with a lesser degree of pre-excitation may still be discriminated. However, caution should be exercised in applying any algorithm where QRS duration approaches 100 ms.

Other limitations of the algorithm include the dependence of the definition of many locations on the precordial transition lead. This may clearly vary within a subject if the criteria for chest lead positioning are not strictly adhered to. Also, in keeping with most surgical studies (6,9), this study began with pathway locations, confirmed by radiofrequency ablation, and then derived rules for an algorithm for pathway localization. We did not test the algorithm produced prospectively in patients with pre-excitation before ablation.

However, unlike many other studies, the statistical methods used are much more appropriate. The discriminant analysis was able to assess the degree of similarity or dissimilarity of each individual ECG variable to all others in the cohort rather than rely on comparison of group means, and this form of analysis is robust with regard to assumption violations when sample sizes are equal or large. When samples are small and unequal, as in left posteroseptal pathways (n = 50) versus left posterolateral pathways (n = 13), the results of significance testing may be less accurate. The algorithm will require prospective evaluation in a new cohort of patients to confirm its value.

Conclusions. We contend that previous ECG methods for pathway location using surgical ablation for accessory pathways as the reference standard have important limitations in the era of radiofrequency catheter ablation. We propose a

Figure 9. Algorithm for defining location of accessory pathways causing pre-excitation of the baseline 12-lead electrocardiogram (ECG). Pathways are initially separated into left and right sided. Right-sided pathways may then be separated into five septal or right lateral locations around the tricuspid valve annulus and left-sided pathways into three septal and lateral locations.
new algorithm for pathway location based on discriminant analysis of pre-excited ECG variables with location confirmed by successful radiofrequency catheter ablation.

References


