Differentiation of Paroxysmal Narrow QRS Complex Tachycardias Using the 12-Lead Electrocardiogram

STEVEN J. KALBFLEISCH, MD, RAFAEL EL-ATASSI, MD, HUGH CALKINS, MD, FACC, JONATHAN J. LANGBERG, MD, FACC, FRED MORADY, MD, FACC
Ann Arbor, Michigan

Objectives. The purpose of this study was to evaluate the utility of the 12-lead electrocardiogram (ECG) for differentiating paroxysmal narrow QRS complex tachycardias.

Background. Previous studies evaluating the utility of the 12-lead ECG for differentiating paroxysmal supraventricular tachycardia types have shown conflicting results on the usefulness of some ECG criteria, and some criteria that are considered to be useful have never been formally evaluated.

Methods. Two hundred forty-two ECGs demonstrating paroxysmal narrow QRS complex (<0.11 ms) tachycardia (rate ≥120 beats/min) were analyzed. All ECGs were analyzed by an observer who had no knowledge of the mechanism of the tachycardia.

Results. There were 137 atrioventricular (AV) reciprocating tachycardias, 93 AV node reentrant tachycardias and 12 atrial tachycardias. Six criteria were found to be significantly different between tachycardia types by univariate analysis. A P wave separate from the QRS complex was observed more frequently in AV reciprocating tachycardia (68%) and atrial tachycardias (75%). A pseudo r' deflection in lead V1 and a pseudo S wave in the inferior leads were more common in AV node reentrant tachycardia (88% and 14%, respectively); QRS alternans was present more often during AV reciprocating tachycardia (27%). When a P wave was present, an RP/PR interval ratio ≥1 was more common in atrial tachycardias (89%). During sinus rhythm, manifest pre-excitation was observed more often in patients with AV reciprocating tachycardia (45%). By multivariate analysis, the presence of a P wave separate from the QRS complex, pseudo r' deflection in lead V1, QRS alternans during tachycardia and the presence of pre-excitation during sinus rhythm were independent predictors of tachycardia type. These criteria correctly identified 86% of AV node reentrant tachycardias, 81% of AV reciprocating tachycardias and incorrectly assigned the tachycardia type in 19% of cases.

Conclusions. Several features on the ECG are useful for differentiating supraventricular tachycardia type. However, approximately 20% of tachycardias may be incorrectly classified on the basis of analysis of the ECG; therefore, the ECG should not serve as the sole means for determining tachycardia mechanism.

J Am Coll Cardiol 1993;21:85-9
was recorded for each patient. Their mean age (±SD) was 36 ± 16 years (range 13 to 83). The ECGs were selected for inclusion in this study if they met the following criteria: 1) regular narrow complex (<0.11 s) supraventricular tachycardia with a 1:1 AV relation, and 2) tachycardia rate ≥120 beats/min. In every patient, the mechanism of paroxysmal supraventricular tachycardia was defined during the electrophysiologic test using standard techniques (7). The 12-lead ECGs were recorded at a paper speed of 25 mm/s, gain setting of 10 mm/mV and filter settings of 0.5 and 1,000 Hz. The limb and precordial leads were recorded as separate groups of six leads each. All leads in each group were recorded simultaneously for 6 s.

ECG analysis. The ECGs were analyzed for the following criteria: 1) rate; 2) cycle length alternans, defined as a beat to beat oscillation in the cycle length of ≥20 ms; 3) QRS alternans, defined as a beat to beat oscillation in QRS amplitude of ≥1 mm in at least one lead; 4) pseudo r' in lead V1, defined as an apparent r' deflection in lead V1 during tachycardia that was not present during sinus rhythm (Fig. 1); 5) pseudo S or Q waves in leads II, III and aVF, defined as an apparent S or Q wave present during tachycardia that was not present during sinus rhythm; 6) the presence of manifest pre-excitation during sinus rhythm; 7) the presence of a discrete deflection consistent with a P wave separate from the QRS complex; and 8) if a P wave was present during paroxysmal supraventricular tachycardia, the RP/PR interval ratio was categorized as either <1 or ≥1.

Some studies reported that the P wave axis during paroxysmal supraventricular tachycardia may be helpful in determining the mechanism of the tachycardia and therefore this criterion originally was included in the analysis of the ECGs in this study. However, when a P wave was present during paroxysmal supraventricular tachycardia, its axis could be determined in the vertical, horizontal and anteroposterior directions in only 32%, 11% and 9% of tachycardias, respectively. Because the P wave axis could be reliably determined in a small number of tachycardias, this criterion was abandoned.

All ECGs were initially analyzed by a single observer who had no knowledge of the tachycardia type. A random subset of 50 ECGs were analyzed by a second observer who also had no knowledge of the tachycardia type and were reanalyzed by the first observer to determine the inter- and intraobserver concordance for categoric variables (Table 1) and the correlation coefficients and mean difference between observations for the continuous variable of rate. The intra- and interobserver rate determinations were highly correlated (r = 0.99 and 0.96 respectively, p < 0.001) and the mean differences for intra- and interobserver rate determinations were not statistically significant (1 ± 4.8 and 0.9 ± 10 beats/min, respectively).

Statistical analysis. The continuous variable of rate was analyzed by using the Scheffé F test analysis of variance to compare the mean rates of different tachycardia types. Other comparisons of rate were performed using the Student unpaired t test. Univariate analysis of discrete variables was performed by contingency table analysis. Multivariate analyses were performed by using the multiple logistic regression technique, having the tachycardia type as the dependent variables and the ECG criteria as the independent variables. Inter- and intraobserver variability were analyzed by using McNemar's chi-square testing for correlated data and Student paired t testing for continuous variables. A p value <0.05 was considered significant.

Results
Among the 242 tachycardias included in this study, 137 (57%) were AV reciprocating tachycardias, 93 (38%) were AV node reentrant tachycardias and 12 (5%) were atrial tachycardias. Six of the criteria analyzed by univariate analysis were found to be significant discriminators of tachycardia mechanism (Table 2). These criteria were the presence of a P wave, a pseudo r' deflection in lead V1, a pseudo S wave in the inferior leads, QRS alternans, pre-excitation during sinus rhythm and the RP/PR interval ratio.

Rate. There were no differences in the mean rates of the three tachycardia types (Table 2). There was no rate cutoff or range of tachycardia rates that was predictive of tachycardia type.

QRS alternans. This pattern was present significantly more often in AV reciprocating tachycardias than in either AV node reentrant or atrial tachycardias (Table 2). The sensitivity, specificity and positive predictive value of QRS alternans for AV reciprocating tachycardia are listed in Table 3.

Tachycardia mechanism and rate were independently associated with the presence of QRS alternans. The mean

![Figure 1](http://example.com/figure1.png)

Figure 1. Pseudo r' deflection (arrow) in lead V1 during tachycardia (A) in a patient with atrioventricular node reentrant tachycardia. This r' deflection was not present during sinus rhythm (B).
rate of the tachycardias that displayed QRS alternans was higher than that of the tachycardias without QRS alternans (201 ± 30 vs. 179 ± 28 beats/min, p = 0.0001). The rate dependence of QRS alternans was also present within the subgroups of AV reciprocating and AV node reentrant tachycardias (Fig. 2).

The mean rate of the tachycardias with QRS alternans was significantly greater in cases of AV node reentrant than AV reciprocating tachycardia (Fig. 2). QRS alternans did not occur in any AV node reentrant tachycardia with a rate <180 beats/min but was present at rates as low as 155 beats/min in AV reciprocating tachycardia. When the tachycardia mechanisms were corrected for rate, QRS alternans was an independent predictor of AV reciprocating tachycardia (p = 0.002).

P waves, RP/PR ratio. A P wave separate from the QRS complex was discernible more often in AV reciprocating tachycardias and atrial tachycardias (Table 2). The sensitivity, specificity and positive predictive value of a P wave for determining tachycardia types are listed in Table 3. When a P wave separate from the QRS complex was present, an RP/PR interval ratio <1 occurred more often with AV reciprocating tachycardia (87%) and AV node reentrant tachycardia (91%) than with atrial tachycardias (11%), and an RP/PR interval ratio ≥1 was more common with atrial tachycardias (89%) than with AV reciprocating tachycardia (13%) or AV node reciprocating tachycardia (9%, p = 0.0001). The sensitivity, specificity and positive predictive value of this criterion are shown in Table 3.

Pseudo r' waves. A pseudo r' wave in lead V1 was present more frequently in AV node reentrant tachycardias than in either AV reciprocating tachycardias or atrial tachycardias (Table 2). The sensitivity, specificity and positive predictive value of a pseudo r' wave in lead V1 for AV node reentrant tachycardia are listed in Table 3.

Only 13 tachycardias had a pseudo S wave in lead II, III or aVF, and all of these were AV node reentrant tachycardias. The sensitivity of a pseudo S wave in the inferior leads for AV node reentrant tachycardia was low (14%), but the specificity and positive predictive value were high (100%). A pseudo Q wave in the inferior leads was never observed.

Cycle length alternans. Cycle length alternans was present in only 6 of the 242 tachycardias; 3 were AV reciprocating tachycardia, 2 were AV node reentrant tachycardia and 1 was an atrial tachycardia. There was no relation between cycle length alternans and tachycardia mechanism.

ECG during sinus rhythm. Manifest pre-excitation was more often present during sinus rhythm with AV reciprocating tachycardias than with either AV node reentrant or atrial tachycardias (Table 2). The sensitivity, specificity and positive predictive value of pre-excitation during sinus rhythm for AV reciprocating tachycardia are listed in Table 3.

Atrophicventricular reciprocating tachycardias were analyzed to determine whether the presence of overt pre-excitation created an observer bias in detecting a P wave during paroxysmal supraventricular tachycardia. Among the AV reciprocating tachycardias, a P wave was detected just as often when there was no overt pre-excitation during sinus rhythm as when there was.

Multivariate analysis. The independent predictors of tachycardia type by multivariate analysis were presence of a P wave during tachycardia, pseudo r' deflection in lead V1, QRS alternans and pre-excitation during sinus rhythm. These criteria correctly identified 86% of AV node reentrant tachycardias and 81% of AV reciprocating tachycardias but incorrectly assigned tachycardia type in 19% of cases. No combinations of criteria were able to reliably differentiate atrial tachycardias from the other two types. The best single

---

Table 2. Univariate Analysis of Electrocardiographic Criteria for Differentiating Tachycardia Types

<table>
<thead>
<tr>
<th>Criteria</th>
<th>AVRT (n = 137)</th>
<th>AVNRT (n = 93)</th>
<th>Atrial Tachycardia (n = 12)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate (beats/min)</td>
<td>184 ± 26</td>
<td>187 ± 35</td>
<td>184 ± 30</td>
<td>NS</td>
</tr>
<tr>
<td>P wave</td>
<td>93 (68%)</td>
<td>111 (25%)</td>
<td>9 (75%)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pseudo r' (V1)</td>
<td>11 (8%)</td>
<td>54 (59%)</td>
<td>1 (8%)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pseudo S (II, III, aVF)</td>
<td>0</td>
<td>13 (14%)</td>
<td>0</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pseudo Q (II, III, aVF)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>QRS alternans</td>
<td>37 (27%)</td>
<td>12 (13%)</td>
<td>0</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Cycle length alternans</td>
<td>3 (2%)</td>
<td>2 (2%)</td>
<td>1 (8%)</td>
<td>NS</td>
</tr>
<tr>
<td>Pre-excitation during sinus rhythm</td>
<td>62 (45%)</td>
<td>2 (2%)</td>
<td>0</td>
<td>0.001</td>
</tr>
</tbody>
</table>

AVNRT = atrioventricular node reentrant tachycardia; AVRT = atrioventricular reciprocating tachycardia.

Table 3. Sensitivity, Specificity and Positive Predictive Value of Selected Criteria for Tachycardia Types

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive Predictive Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVRT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P wave present</td>
<td>68</td>
<td>81</td>
<td>82</td>
</tr>
<tr>
<td>RP/PR interval ratio &lt;1</td>
<td>87</td>
<td>45</td>
<td>88</td>
</tr>
<tr>
<td>QRS alternans</td>
<td>27</td>
<td>88</td>
<td>76</td>
</tr>
<tr>
<td>Pre-excitation during sinus rhythm</td>
<td>45</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>AVNRT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo r'</td>
<td>58</td>
<td>91</td>
<td>82</td>
</tr>
<tr>
<td>Pseudo S</td>
<td>14</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Atrial tachycardia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P wave present</td>
<td>75</td>
<td>55</td>
<td>8</td>
</tr>
<tr>
<td>RP/PR interval ratio ≥1</td>
<td>89</td>
<td>88</td>
<td>38</td>
</tr>
</tbody>
</table>

Abbreviations as in Table 2.
predictors for AV node reentrant and AV reciprocating tachycardia were the presence of a pseudo r' deflection in lead V1 during tachycardia and pre-excitation during sinus rhythm, respectively.

A second multivariate analysis that included only features present during tachycardia and excluded the presence of pre-excitation during sinus rhythm demonstrated the presence of a P wave, pseudo r' deflection in lead V1, and QRS alternans to be independent predictors of tachycardia type. These criteria correctly identified 58% of AV node reentrant and 92% of AV reciprocating tachycardias and incorrectly assigned the tachycardia type in 23% of cases. In this analysis, the single best predictors of AV node reentrant and AV reciprocating tachycardias were a pseudo r' deflection in lead V1 and the presence of a P wave, respectively.

Discussion

Main findings. This study represents the largest series of narrow QRS complex tachycardias analyzed to determine the utility of various ECG criteria in distinguishing the mechanism of paroxysmal supraventricular tachycardia. The criteria predictive of AV reciprocating tachycardia were the presence of a P wave distinct from the QRS complex, an R/P ratio <1, QRS alternans and pre-excitation during sinus rhythm. The criteria predictive of AV node reentrant tachycardia were the presence of a pseudo r' deflection in lead V1, or pseudo S wave in the inferior leads. The criteria predictive of atrial tachycardia were the presence of a P wave with an R/P ratio ≥1.

This study shows that several features present on the ECG during paroxysmal supraventricular tachycardia may be helpful in differentiating tachycardia types. The criteria analyzed were able to accurately diagnose approximately 80% of cases of AV reciprocating and AV node reentrant tachycardia but were unable to reliably differentiate atrial tachycardias.

Tachycardia rate. In this study, tachycardia rate was not helpful in distinguishing the mechanisms of paroxysmal supraventricular tachycardia. In contrast, two studies (4,5) with smaller sample sizes reported that AV reciprocating tachycardias tend to have faster rates than either AV node reentrant tachycardias or atrial tachycardias. However, another study (3) also found no difference in the mean rates of the three general types of tachycardia. The present study, and the study by Bär et al. (2), which are the two largest studies evaluating the criterion of rate, demonstrate convincingly that tachycardia rate is not helpful in determining the mechanism of paroxysmal supraventricular tachycardia.

QRS alternans. Previous studies (8) examining the significance of QRS alternans have had conflicting results. Green et al. (1) and Bär et al. (2) found QRS alternans to be highly predictive of AV reciprocating tachycardias, whereas Morady et al. (3) and Kay et al. (4) did not find this to be the case. The latter two groups found QRS alternans to be a rate-related phenomenon that was independent of tachycardia mechanism.

The present study demonstrates that QRS alternans is dependent on both tachycardia type and rate. Within each tachycardia type, the presence of QRS alternans was dependent on tachycardia rate and when the tachycardia types were corrected for rate, the presence of QRS alternans was still an independent predictor for AV reciprocating tachycardia. The reason that QRS alternans occurs more frequently at faster rates may be explained by oscillations in the relative refractory period of the specialized conducting system as a result of alternating action potential duration (9), but the reason that it occurs more frequently with AV reciprocating tachycardia is an interesting and as yet unexplained phenomenon.

P waves. The presence of a P wave separate from the QRS complex during tachycardia was found to be predictive of either AV reciprocating tachycardia or atrial tachycardia. This finding is in accord with the results of prior studies (2,4,5). The interobserver and intraobserver concordance for this criterion were the lowest, both 80%, and therefore the reliability of this criterion for accurately determining tachycardia type is less than that of the other criteria.

When a P wave separate from the QRS complex is
detected, the RP/PR interval ratio is helpful in differentiating the tachycardia type. An RP/PR interval ratio $\geq 1$ is more often observed in atrial tachycardias and an RP/PR interval ratio $<1$ is more common with AV reciprocating and AV node reentrant tachycardias. Because the number of atrial tachycardias in this study was small (12 among the 242 total patients), the positive predictive value of an RP/PR interval ratio $\geq 1$ is only 38%. These results indicate that if a P wave separate from the QRS complex is present, the diagnosis of AV reciprocating tachycardia is most likely, especially if the RP/PR interval ratio is $<1$; however, if the RP/PR interval ratio is $\geq 1$, atrial tachycardia should also be considered. These results are in concordance with previous studies (2,5,10) evaluating the significance of the RP/PR interval ratio.

Determination of the P wave axis was usually not feasible and therefore this criterion was not used in our analysis of results. Kay et al. (4) also found that a P wave axis could not be determined in the majority of their cases and that when the axis could be determined, it did not add any incremental value for differentiating tachycardia types.

Pseudo r' and S waves. This is the first study to specifically evaluate the usefulness of detecting a pseudo r' deflection in lead V', or a pseudo S or Q wave in leads II, III and aVF for differentiating tachycardia types. The presence of either a pseudo r' deflection in lead V', or a pseudo S wave in the inferior leads was highly predictive of AV node reentrant tachycardia.

The occurrence of a pseudo r' deflection in lead V', or a pseudo S wave in leads II, III and aVF during AV node reentrant tachycardia is due to a retrograde P wave that distorts the normal QRS configuration. Another possible explanation for the presence of an r' deflection in lead V', during tachycardia that is not present during sinus rhythm would be a rate-related right ventricular conduction delay. This is a potential source of error when looking for a pseudo r' deflection.

Limitations of the study. 1) Only patients referred for electrophysiologic testing were included and therefore this series may not be representative of all narrow QRS complex tachycardias. For example, patients who have relatively slow paroxysmal supraventricular tachycardias may be less symptomatic and less likely to be referred for electrophysiologic testing, creating a possible selection bias toward patients who have more rapid paroxysmal supraventricular tachycardias. 2) There were only a small number of atrial tachycardias in this study, which limited the statistical analysis of this type of paroxysmal supraventricular tachycardia. This has also been a problem in previous studies (2,5) and may reflect the fact that atrial tachycardias are much less common than the other two types of paroxysmal supraventricular tachycardia. 3) No attempt was made to differentiate the subtypes of AV node reentrant tachycardia (typical vs. atypical) or AV reciprocating tachycardia (those using slowly or rapidly conducting accessory pathways). Tachycardias were categorized into only three general mechanisms to simplify the application of the results to the clinical setting. 4) An ECG recorded during sinus rhythm was necessary to establish the presence of some of the ECG criteria used in this study. If a sinus rhythm ECG is not available at the time a patient presents with ongoing paroxysmal supraventricular tachycardia, criteria such as the presence of a pseudo r' deflection or overt pre-excitation during sinus rhythm cannot be evaluated until the paroxysmal supraventricular tachycardia has been terminated. In patients with incomplete right bundle branch block during sinus rhythm, the pseudo r' criterion cannot be used. 5) Only narrow QRS complex supraventricular tachycardias were analyzed. Therefore, no comment can be made about how these criteria apply to patients with wide complex supraventricular tachycardia.

Conclusions. Electrocardiographic criteria are able to accurately identify approximately 80% of AV node reentrant and AV reciprocating tachycardias, but incorrectly categorize approximately 20% of paroxysmal supraventricular tachycardias and are unable to differentiate atrial tachycardias from the other two types. Therefore, the ECG cannot serve as the sole means for determining the mechanism of the tachycardia. Knowledge gained from the ECG may be helpful when planning an electrophysiologic test, especially when catheter-based procedures are contemplated because the approach used and risks involved are different for the different tachycardia types.

We are grateful to Marion Maguire for expert assistance in the preparation of the manuscript.

---

References