Differentiation of Narrow QRS Complex Tachycardia Types Using the 12-Lead Electrocardiogram

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Background: Previous studies have shown that only 80% of narrow QRS supraventricular tachycardia (SVT) types can be differentiated by standard 12-lead electrocardiographic (ECG) criteria. This study was designed to determine the value of some new ECG criteria in differentiating narrow QRS SVT.

Methods and Results : 120 ECGs demonstrating paroxysmal narrow QRS complex tachycardia ($QRS \leq 0.11$ ms and rate > 120 beats/min) were analyzed. Forty atrioventricular reciprocating tachycardia (AVRT), 70 atrioventricular nodal reentrant tachycardia (AVNRT), and 10 atrial tachycardia defined with electrophysiologic study (EPS) consisted the study group. Eight surface ECG criteria were found to be significantly different between tachycardia types by univariate analysis. P waves separate from the QRS complex were observed more frequently in AVRT (70%) and atrial tachycardia (80%). Pseudo r' deflection in lead V¹, pseudo S wave in inferior leads, and cycle length alternans were more common in AVNRT (55, 20, and 6%, respectively). QRS alternans was also present during AVRT (28%). ST-segment depression (≥ 2 mm) or T-wave inversion, or both, were present more often in AVRT (60%) than in AVNRT (27%). During sinus rhythm, manifest preexcitation was observed more often in patients with AVRT (42%). When a P wave was present, RP/PR interval ratio > 1 was more common in atrial tachycardia (90%). By multivariate analysis, presence of a P wave separate from the QRS complex, pseudo r' deflection in lead V¹, QRS alternans, preexcitation during sinus rhythm, ST-segment depression > 2 mm or T-wave inversion, or both, were independent predictors of tachycardia type.

Conclusions: Several new ECG criteria may be useful in differentiation of SVT types. Prediction of mechanism prior to EPS may provide additional benefits concerning the fluoroscopic exposure time and cardiac catheterization procedure.

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narrow QRS tachycardia; electrocardiography; electrophysiologic study; diagnosis

Catheter ablation using radiofrequency energy is an important method in the treatment of symptomatic SVT.^{1,2} Noninvasive differentiation of the type of narrow QRS SVT (AVNRT, AVRT, and atrial tachycardia) before catheter ablation may be helpful in planning ablation procedure, decreasing fluoroscopy time, and choosing pharmacological treatment. If responsible regions are known before EPS, the possibility of mechanical trauma on the

pathways caused by the electrode catheter can be minimized.³

Several noninvasive 12-lead ECG criteria including heart rate, QRS alternans, cycle length alternans, PR/RP interval ratio, separate P wave, presence of r' in V¹, and presence of pseudo S or Q wave in inferior leads have been identified to differentiate the three types of SVT.⁴⁻¹¹ However these criteria have some conflicting points. For ex-

Figure 1. QRS alternans, defined as beat-to-beat oscillation in QRS amplitude of > 1 mm in at least one lead. 12-lead ECG with horizontal ST segment depressions persisting 80 ms beyond J point during SVT.

ample, in several studies QRS alternans during SVT was found to be highly predictive of AV reciprocating tachycardia,^{7,11} whereas some authors did not find it as predictive.⁴ Similarly, although there is some evidence regarding the usefulness of P-wave axis,⁷ it is sometimes impossible to determine the axis of P wave in all patients.⁸ In contrast, the diagnostic value of repolarization changes occurring during SVT were evaluated only in a few studies.¹²⁻¹⁴ We sought the value of repolarization changes additional to these criteria in order to increase the specificity and sensitivity of 12-lead ECG analysis in differentiation of tachycardia mechanisms.

METHODS

One hundred twenty patients (mean age 37 ± 14 years, range 14-71) with narrow QRS SVT were included in the study between 1997 and 2000. Inclusion criteria were the presence of a regular narrow QRS complex (≤ 0.11 ms) tachycardia with a 1:1 relation of AV activity. Exercise stress testing and echocardiography were performed for exclusion of the patients with structural heart disease.

ECG Recordings

We evaluated 120 standard 12-lead ECG recorded during both sinus rhythm and paroxysmal

SVT at the time of EPS for each patient. ECG samples were recorded at a paper speed of 25 mm/s, gain setting of 10 mm/mV, and filter setting of 0.5 and 100 Hz. The precordial and limb leads were recorded as separate groups of six leads each. All leads in each group were recorded simultaneously at least for 6 seconds.

The mechanism of the tachycardia was determined during the EPS by using standard techniques including atrial extra-stimulus testing and overdrive pacing.¹⁶

ECG Analysis

Each ECG was analyzed for the following criteria: (1) Rate; (2) Cycle length alternans, defined as beat to beat oscillation in cycle length of > 120 ms; (3) QRS alternans, defined as beat to beat oscillation in QRS amplitude of > 1 mm in at least one lead (Fig. 1); (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 2); (5) Pseudo S or Q waves in inferior leads, defined as an apparent S or Q wave during tachycardia that was not present during sinus rhythm (Fig 3); (6) The presence of manifest preexcitation during sinus rhythm; (7) The presence of discrete deflection consistent with a P wave separate from the QRS complex (Fig. 4); (8) If a P wave was present during

Figure 2. Pseudo r' wave in lead V¹ during tachycardia (A), which was not present during sinus rhythm (B).

paroxysmal SVT, the RP/PR interval ratio was categorized as either < 1 or > 1 (Fig 4); (9) ST-segment changes, defined as horizontal or down sloping ST-segment depression of > 2 mm, persisting 80 ms beyond J point during SVT (Fig. 1); (10) Inversion of T wave during SVT that was positive in some leads during sinus rhythm. An experienced cardiologist who had no knowledge about the type of the tachycardia initially analyzed all ECGs. A second observer who also had no knowledge of the tachycardia type analyzed a random subset of 40 ECGs. The first observer reanalyzed the ECGs to determine the intraobserver concordance for categorical variables (Table 1).

Statistical Analysis

Data expressed as mean $\pm$ SD. When appropriate, the following tests were performed. Student unpaired *t* test; Scheffe F test analysis of variance by SPSS; univariate analysis of discrete variables

was performed with contingency table analysis; multivariate analyses were performed by using the multiple logistic regression technique; McNemar's chi square testing; and linear regression analysis. A P value of < 0.05 was considered significant.

RESULTS

Of the 120 narrow QRS complex tachycardia included in the study, 40 were AVRT, 70 were AVNRT, and 10 were atrial tachycardia. Eight 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 inferior leads, QRS alternans, preexcitation during sinus rhythm, RP/PR interval ratio, ST-segment depression or T-wave inversion, or both. The sensitivity, specificity, and positive predictive values of each criterion are listed in Table 3.

Figure 3. Pseudo S wave in Lead II during tachycardia (A), and disappearance of this deflection with restoration of sinus rhythm (B).

Figure 4. ECG strips showing P wave separate from the QRS complex and long RP tachycardia. RP/PR interval ratio categorized as either < 1 or > 1 .

Rate

Mean heart rates were similar in all groups and the range of the tachycardia rates was not predictive of tachycardia type.

QRS Alternans

This parameter was more frequently present in AVRT than in other types of SVTs. On the other hand, QRS alternans was found to be dependent to the tachycardia rate. The rate of the tachycardia was statistically higher in SVTs with QRS alternans than those without QRS alternans (208 ± 20 beats/min vs 168 ± 25 beats/min, $P: 0.0001$). QRS alternans could only be observed in high rate AVNRT. However, QRS alternans was present in low rate AVRT.

P Waves

A P wave separate from the QRS complex was more frequent in AVRT and atrial tachycardia.

RP/PR Interval Ratio

The presence of a P wave separate from QRS complex allowing the evaluation of RP/PR interval ratio was important in differentiation of the tachycardia type. While RP/PR interval ratio was > 1 in 90% of atrial tachycardia, it was < 1 in 85% of AVRT, and 90% of AVNRT.

Pseudo r' Wave

A pseudo r' in lead V¹ was present more frequently in AVNRT than in either AVRT or atrial tachycardia.

Pseudo S Wave

Only 14 ECGs had a pseudo S wave in leads II, III, aVF, and all of these were AVNRT. Pseudo S wave was not observed in AVRT and atrial tachycardia.

Pseudo Q Wave

Q waves were not observed in all supraventricular tachycardia types during SVT.

Cycle Length Alternans

Cycle length alternans were observed in 4 AVNRT, 2 AVRT, and 1 atrial tachycardia. There was no relationship between cycle length alternans and tachycardia mechanism.

Preexcitation during Sinus Rhythm

Manifest preexcitation was present more often during sinus rhythm with AVRT than either AVNRT and atrial tachycardia.

ST-segment Depression ≥ 2 mm or T-wave Inversion, or Both

ST-segment depression ≥ 2 mm was significantly more frequent in AVRT than in AVNRT and atrial tachycardia. The magnitude of ST-segment depression was also greater in AVRT than in AVNRT. Correlation was searched between cycle length and ST-segment depression to evaluate the effects of

Table 1. Inter- and Intraobserver Concordance of the Analysis of Electrocardiographic Criteria

	Interobserver (%)	Intraobserver (%)
P wave	82	80
RP/PR interval ratio	96	96
Pseudo r' (V1)	94	98
Pseudo S (II, III, aVF)	94	97
Pseudo Q (II, III, aVF)	100	100
QRS alternans	97	93
Cycle length alternans	100	100
Pre-excitation during sinus rhythm	99	99

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

Criteria	AVRT n: 40	AVNRT n: 70	AT n: 10	P Value
Rate (beats/min)	184 ± 20	186 ± 30	182 ± 28	NS
P wave	28 (70%)	10 (14%)	8 (80%)	0.0001
Pseudo r' (V1)	3 (7.5%)	38 (55%)	1 (10%)	0.0001
Pseudo S (II, III, aVF)	0 (0%)	14 (20%)	0 (0%)	0.0001
Pseudo Q (II, III, aVF)	0 (0%)	0 (0%)	0 (0%)	NS
QRS alternans	8 (20%)	7 (10%)	0 (0%)	0.01
Cycle length alternans	2 (5%)	4 (6%)	1 (10%)	NS
Pre-excitation during sinus rhythm	17 (42%)	0 (0%)	0 (0%)	0.0001
ST > 2 mm or T inversion or both	24 (60%)	19 (27%)	1 (10%)	0.001
Magnitude of ST depr (mm)	1.5 ± 1.4	0.6 ± 0.8	0.3 ± 0.5	0.002

AVRT = atrioventricular reciprocating tachycardia; AVNRT = atrioventricular nodal reentrant tachycardia; AT = atrial tachycardia.

heart rate on the presence and magnitude of ST-segment depression. There was no correlation between tachycardia cycle length and ST-segment depression in AVNRT (r : 0.20, P : 0.06). A weak correlation was observed in AVRT (r : 0.45, P : 0.0001).

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, preexcitation during sinus rhythm, ST-segment depression $\geq$ 2 mm or T-wave inversion, or both.

DISCUSSION

Analysis of P-QRS relationship, distinct pattern of P wave (pseudo r' wave in lead V¹, pseudo S wave in inferior leads), and the presence of QRS alternans are the standard criteria in diagnosing the mechanism of SVT. With this study we evaluated the repolarization changes additional to standard criteria.

The value of heart rate in differentiation of the SVT mechanism is still indefinite. Mean heart rates were not significantly different in our study groups. Although several studies showed that AVRT has relatively faster rate than AVNRT and atrial tachycardia,^{4,8} the range of the tachycardia rates was not found as a predictor of tachycardia type in larger studies.^{7,9,10}

Retrograde P wave is partially or fully concealed within the QRS complex during AVNRT and when visible appears as a distortion of normal QRS complex. Pseudo r' wave in lead V¹ may be a conse-

quence of distorted QRS complex by P wave or may be related with right ventricular conduction delay during tachycardia. The presence of a separate P wave may be useful in diagnosis of SVT mechanism. In our study a separate P wave was found as a predictive criteria for AVRT and atrial tachycardia. Since the intra- and interobserver concordance of this criterion was 82% and 80%, re-

Table 3. Sensitivity, Specificity and Positive Predictive Values of Surface ECG Criteria in Differentiation of Supraventricular Tachycardia Types

	Sensitivity (%)	Specificity (%)	PPV (%)
AVRT			
P wave	70	74	60
Pseudo r'	7	51	7
QRS alternans	20	91	53
Cycle length alternans	5	93	28
Pre-excitation	42	100	100
ST > 2 mm	60	75	54
AVNRT			
P wave	14	35	21
Pseudo r'	54	92	90
Pseudo S	20	100	100
QRS alternans	10	84	46
Cycle length alternans	5	94	57
ST > 2 mm	27	50	43
Atrial tachycardia			
P wave	80	65	17
Pseudo r'	10	62	2
Cycle length alternans	10	94	14

AVRT = atrioventricular reciprocating tachycardia; AVNRT = atrioventricular nodal reentrant tachycardia; PPV = positive predictive value.

spectively, similar to previous studies,⁷⁻⁹ it has a low reliability in the diagnosis of the mechanism of the tachycardia. Analysis of P wave axis is also another useful criteria⁷ but in several studies it has been found impossible to calculate the P-wave axis^{8,9} in most patients. The ratio of RP/PR interval > 1 is definitive for atrial tachycardia, but in case of the ratio < 1 the diagnosis may be AVNRT or AVRT. In our study in 9 of 10 atrial tachycardia the RP/PR ratio was > 1 and this result was similar to previous studies assessing the RP/PR interval.^{7,9}

Presence of pseudo r' wave in lead V¹ and pseudo S wave in leads II, III, aVF is a crucial finding in differentiation of AVNRT from AVRT and atrial tachycardia. Pseudo r' wave in lead V¹ has been observed in 32% AVNRT and only in 2% AVRT in a study that was performed in 100 patients with narrow QRS SVT.¹⁷ In the same study, while pseudo S wave was not observed in both AVRT and atrial tachycardia, the incidence of pseudo S wave in inferior leads was found to be 24% in AVNRT. In our study the incidence of pseudo r' wave in lead V¹ and pseudo S wave in inferior leads in AVNRT were 55% and 20%, respectively. The high incidence of these findings was similar to a study performed by Kalbfleisch et al.⁹

The presence of electrical QRS alternans during narrow complex tachycardia depends on both the type and rate of the tachycardia. Changes in action potential duration and oscillation of relative refractory periods in conduction system may be responsible for QRS alternans.⁹ In AVNRT and AVRT the presence of QRS alternans was dependent on the tachycardia rate. This finding is present in only a small proportion of cases with rapid AVNRT. When tachycardia types are corrected for rate, the presence of QRS alternans is still an independent predictor for AVRT.¹¹

ST-segment depression ≥ 2 mm and T-wave inversion is more frequent in AVRT compared to AVNRT and atrial tachycardia. The magnitude of the ST-segment depression in AVRT was greater than AVNRT (1.5 ± 1.4 mm vs 0.6 ± 0.8 mm, respectively, $P: 0.002$). The grade of ST-segment depression is still similar after correction with heart rate. ST-segment depression may be a consequence of longer ventriculo-atrial interval and longer retrograde P-wave duration in AVRT.¹⁵ Several patterns of repolarization changes have also been shown to be associated with a specific accessory pathway location, for example, ST-segment

depression in lead V³-V⁶ in patients with left lateral accessory pathway, ST-segment depression and negative T wave in inferior leads in patients with posteroseptal or posterior accessory pathway, and a negative or notched T wave in lead V² in patients with an anteroseptal pathway have found to be almost specific repolarization changes for these accessory pathway locations.¹⁵

CONCLUSIONS

This is the first study evaluating the repolarization changes during tachycardia additional to standard criteria in differential diagnosis of the paroxysmal SVT. According to the results of the study, the predictive criteria of AVRT are presence of a separate P wave, RP/PR < 1 , alternans of QRS, ST depression or T-wave inversion or both, and the presence of preexcitation during sinus rhythm. The predictive criteria for AVNRT are pseudo r' deflection in V¹ and pseudo S wave in inferior leads. RP/PR ratio > 1 and a separate P wave are predictive criteria for atrial tachycardia.

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