Differentiation of Atypical Atrioventricular Node Re-Entrant Tachycardia From Orthodromic Reciprocating Tachycardia Using a Septal Accessory Pathway by the Response to Ventricular Pacing

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OBJECTIVES
The purpose of this study was to determine whether the response to ventricular pacing during tachycardia is useful for differentiating atypical atrioventricular node re-entrant tachycardia (AVNRT) from orthodromic reciprocating tachycardia (ORT) using a septal accessory pathway.

BACKGROUND
Although it is usually possible to differentiate atypical AVNRT from ORT using a septal accessory pathway, a definitive diagnosis is occasionally elusive.

METHODS
In 30 patients with atypical AVNRT and 44 patients with ORT using a septal accessory pathway, the right ventricle was paced at a cycle length 10 to 40 ms shorter than the tachycardia cycle length (TCL). The ventriculo-atrial (VA) interval and TCL were measured just before pacing. The interval between the last pacing stimulus and the last entrained atrial depolarization (stimulus-atrial [S-A] interval) and the post-pacing interval (PPI) at the right ventricular apex were measured on cessation of ventricular pacing.

RESULTS
All 30 patients with atypical AVNRT and none of the 44 patients with ORT using a septal accessory pathway had an S-A–VA interval $\geq$ 85 ms and PPI–TCL $\geq$ 115 ms.

CONCLUSIONS
The S-A–VA interval and PPI–TCL are useful in distinguishing atypical AVNRT from ORT using a septal accessory pathway.

The difference between the post-pacing interval (PPI) and tachycardia cycle length (TCL) has been helpful in assessing the proximity of the pacing site to a re-entry circuit (1). Because it is sometimes difficult to differentiate atypical atrioventricular node re-entrant tachycardia (AVNRT) from orthodromic reciprocating tachycardia (ORT) using a septal accessory pathway, a simple diagnostic maneuver that reliably distinguishes these two types of tachycardia would be valuable. We postulated that the PPI might be helpful in distinguishing AVNRT from ORT using a septal accessory pathway. Because a right ventricular (RV) pacing site is nearer to the re-entry circuit for ORT, the PPI theoretically should more closely approximate the TCL than it would for AVNRT. For the same reason, the stimulus-atrial (S-A) interval during RV entrainment would be expected to more closely approximate the ventriculo-atrial (VA) interval measured during tachycardia. The purpose of this study was to determine whether the response to ventricular pacing during tachycardia is useful for differentiating atypical AVNRT from ORT using a septal accessory pathway.

METHODS

Patient characteristics. This retrospective study included 30 patients with atypical AVNRT and 44 patients with ORT using a septal accessory pathway, who underwent radiofrequency ablation at the University of Michigan Medical Center. The study was approved by the Human Research Committee at the University of Michigan Medical Center. Their mean age was 39 ± 14 years; there were 44 men and 30 women. Seven patients had an anteroseptal accessory pathway; 3 patients had a mid-septal accessory pathway; 23 patients had a right posteroseptal accessory pathway; and 11 patients had a left posteroseptal accessory pathway. Twenty-five of 30 patients with AVNRT and 29 of 44 patients with ORT using a septal accessory pathway, had a long RP tachycardia, defined as an RP/RR ratio $\geq$ 0.50. Patients in whom the tachycardia mechanism was not clear, based on conventional criteria (n = 4), or in whom entrainment from the RV could not be performed (n = 5) were excluded. No patient had structural heart disease.

Electrophysiologic procedure. Electrophysiologic tests were performed in the fasting state. The patients' written, informed consent was obtained before sedation. Quadrupolar electrode catheters were inserted into a femoral vein and positioned in the high right atrium and RV apex or septum. A roving quadripolar catheter was moved between the anteroseptal tricuspid valve (His bundle recording) and

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coronary sinus positions. At least four electrocardiographic leads and intracardiac electrograms were recorded and stored on either the EPLab (Quinton Electrophysiology Corp., Seattle, Washington) or EP-WorkMate (EP MedSystems, Inc., Mt. Arlington, New Jersey) recording systems. Bipolar intracardiac electrograms were filtered between 30 and 500 kHz and recorded from the proximal electrode pair at a speed of 100 mm/s. Bipolar pacing was performed at twice the diastolic threshold from the distal electrode pair by using a Bloom DTU 210 (Bloom Associates, Narberth, Pennsylvania) or an EP MedSystems programmable stimulator. All patients had a single mechanism of paroxysmal supraventricular tachycardia that was successfully eliminated by radiofrequency catheter ablation.

Atrial tachycardia was excluded in all patients by the presence of an atrial-ventricular (AV) response after entrainment of the tachycardia from the RV (2). The diagnosis of atypical AVNRT was made when the VA interval in the high right atrium was ≥100 ms, the earliest retrograde atrial activation was in the atrial septum and one or more of the following criteria were satisfied: 1) AV block during tachycardia (3); 2) AV dissociation with rapid ventricular pacing at a cycle length between 200 and 250 ms during tachycardia (4); 3) a delta atrial-His bundle (AH) interval >40 ms (5); and 4) a delta His-atrial (HA) interval >−10 ms (6).

The diagnosis of ORT was made when the earliest retrograde activation was in the atrial septum in the absence of the aforementioned criteria, and one or more of the following criteria were satisfied: 1) the tachycardia was reset or terminated by a premature ventricular depolarization that occurred when the His bundle was refractory (3); and 2) the VA interval during tachycardia increased by ≥10 ms, with the development of functional bundle branch block (7).

Entrainment of the tachycardia was attempted by pacing the RV at a cycle length 10 to 40 ms shorter than the TCL. Entrainment was confirmed when the atrial cycle length accelerated to the pacing cycle length, without a change in the atrial activation sequence, and the tachycardia resumed after pacing was discontinued. The longest paced cycle length clearly resulting in entrainment was used for analysis. The TCL and interval between the onset of the QRS complex and the high right atrial electrogram (VA interval) were measured in the cycle immediately before pacing. The maximal spontaneous variability in TCL was 30 ms in this study. The S-A interval was measured from the last RV pacing stimulus during entrainment to the last entrained atrial depolarization in the high right atrium. The PPI was measured from the last RV pacing stimulus to the RV electrogram in the first return beat. Examples of these measurements are shown for atypical AVNRT (Fig. 1) and ORT using a septal accessory pathway (Fig. 2).

Statistical analysis. Continuous variables are expressed as the mean value ± SD. Continuous variables were analyzed using the Student t test. Nominal variables were compared

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**Figure 1.** Entrainment of atrioventricular node re-entrant tachycardia (AVNRT) from the right ventricular septum (RVS) at a cycle length of 510 ms. (A) The ventriculo-atrial (VA) interval and tachycardia cycle length (TCL) are measured immediately before entrainment. (B) The stimulus-atrial (S-A) interval is measured from the last pacing stimulus to the last entrained high right atrial (HRA) electrogram, and the post-pacing interval (PPI) is measured from the last pacing stimulus to the return cycle RV electrogram. The S-A–VA interval is 120 ms, and the PPI–TCL is 150 ms. HBd = His bundle distal; S = stimulus.
by Pearson chi-square analysis. A p value <0.01 was considered statistically significant after Bonferroni adjustment for multiple comparisons.

RESULTS

Basic measurements. Significant differences in mean values for the VA interval, S–A interval, PPI, S–A–VA interval and PPI–TCL were observed between patients with atypical AVNRT and ORT using a septal accessory pathway (Table 1). No significant difference in the TCL was observed.

The S–A–VA interval. A discriminant value for the S–A–VA interval was chosen midway between the lowest value measured in all patients with atypical AVNRT and the highest value measured in all patients with ORT using a septal accessory pathway (Fig. 3). All patients with atypical AVNRT had a S–A–VA interval 85 ms (range 90 to 200), and all patients with ORT using a septal accessory pathway had a S–A–VA interval 85 ms (range 0 to 80).

The PPI–TCL. Likewise, a discriminant value for the PPI–TCL was chosen midway between the lowest value measured in all patients with atypical AVNRT and the maximal value measured in all patients with ORT using a septal accessory pathway (Fig. 4). All patients with AVNRT had a PPI–TCL >115 ms (range 140 to 260), and all patients with ORT using a septal accessory pathway had a PPI–TCL <115 ms (range 0 to 95).

DISCUSSION

Major findings. In this study, the response to RV pacing was found to be useful in distinguishing atypical AVNRT from ORT using a septal accessory pathway. An S–A–VA

| Table 1. Interval Measurements Used to Distinguish Atypical Atrioventricular Node Re-Entrant Tachycardia From Orthodromic Re-Entrant Tachycardia Using a Septal Accessory Pathway |
|----------------------------------|----------------------------------|----------------------------------|
|                                   | Atypical AVNRT (n = 30)          | ORT Using a Septal AP (n = 44)   | p Value |
| TCL                              | 356 ± 82 (240–495)               | 317 ± 62 (270–560)               | 0.03    |
| VA interval                      | 234 ± 73 (100–410)               | 182 ± 66 (120–500)               | 0.002   |
| S–A interval                     | 381 ± 75 (225–615)               | 212 ± 70 (130–450)               | <0.001  |
| PPI                              | 536 ± 88 (430–750)               | 378 ± 57 (290–550)               | <0.001  |
| S–A–VA interval                  | 146 ± 21 (140–260)               | 30 ± 21 (0–95)                   | <0.001  |
| PPI–TCL                          | 180 ± 29 (90–200)                | 61 ± 24 (0–80)                   | <0.001  |

Data are presented as the mean value ± SD and range (in parentheses) for interval measurements (all in ms) used to distinguish atypical atrioventricular node reentrant tachycardia (AVNRT) from orthodromic reentrant tachycardia (ORT) using a septal accessory pathway.

PPI = post-pacing interval; S–A = stimulus-atrial; TCL = tachycardia cycle length; VA = ventriculoatrial.

Figure 2. Entrainment of orthodromic reciprocating tachycardia (ORT) using a right posteroseptal bypass tract from the right ventricular apex (RVA) at a cycle length of 440 ms. (A) The ventriculo-atrial (VA) interval and tachycardia cycle length (TCL) are measured immediately before entrainment. (B) The stimulus-atrial (S–A) interval is measured from the last pacing stimulus to the last entrained high right atrial (HRA) electrogram, and the post-pacing interval (PPI) is measured from the last pacing stimulus to the return cycle RV electrogram. The S–A–VA interval is 40 ms, and the PPI–TCL is 80 ms. HBD = His bundle distal; S = stimulus.

Figure 3. Scatterplot showing the mean value ± SD of the stimulus-atrial–ventriculo-atrial (S–A–VA) interval (ms) for patients with either orthodromic reciprocating tachycardia (ORT) using a septal accessory pathway or atypical atrioventricular node re-entrant tachycardia (AVNRT). The line drawn at 85 ms represents the discriminant point distinguishing the two forms of long VA tachycardia.
interval $>85$ ms and PPI–TCL $>115$ ms were seen in all patients with atypical AVNRT and in none of the patients with ORT using a septal accessory pathway.

As shown in Figures 3 and 4, the PPI–TCL is the stronger of the two criteria, because these values for patients with atypical AVNRT and those with ORT using a septal accessory pathway, are farther apart than the values for the S-A–VA interval. Although there were significant differences in the mean TCL, VA interval, S-A interval and PPI among patients with AVNRT and those with ORT using a septal accessory pathway, the individual values overlapped to an extent that these intervals are not clinically useful by themselves.

**Mechanism.** Atypical AVNRT and ORT using a septal accessory pathway, both use the AV node as the anterograde limb of the re-entry circuit. Atypical AVNRT uses a slow AV node pathway as the retrograde limb, and neither the atrium nor the ventricle is an obligatory part of the tachycardia circuit. In contrast, ORT uses an AV pathway as the retrograde limb, and both the atrium and ventricle are obligatory components of the tachycardia circuit. Because the RV apex and septum are closer to and part of the tachycardia circuit in ORT using a septal accessory pathway, one would expect the S-A interval during entrainment from the RV to more closely approximate the VA interval in ORT, as compared with atypical AVNRT, as was the case in this study.

In atypical AVNRT, the PPI reflects the conduction time from the pacing catheter through the RV muscle and His-Purkinje system, once around the re-entry circuit and back. The PPI–TCL reflects twice the sum of the conduction time through the RV muscle and His-Purkinje system. In ORT using a septal accessory pathway, the PPI reflects the conduction time through the RV to the septum, once around the re-entry circuit and back. The PPI–TCL reflects twice the conduction time from the pacing catheter through the ventricular myocardium to the re-entry circuit. Therefore, the PPI more closely approximates the TCL in ORT using a septal accessory pathway, compared with atypical AVNRT, as demonstrated in this study.

Importantly, there was no overlap between the maximal value of PPI–TCL or S-A–VA measured for patients with posteroseptal accessory pathways and the minimal value of PPI–TCL and S-A–VA measured for patients with atypical AVNRT.

The PPI–TCL was a stronger discriminator of the tachycardia mechanism than was the S-A–VA interval. This is probably because the PPI reflects both retrograde and anterograde conduction, whereas the S-A interval reflects only retrograde conduction.

**Previous studies.** Useful maneuvers have been developed to distinguish atypical AVNRT from ORT using a posteroseptal accessory pathway. Man et al. (5) found that a delta AH interval $>40$ ms was associated with atypical AVNRT, but $\sim 17\%$ of atypical AVNRTs had a delta AH interval less than the discriminant value. Miller et al. (6) found that a delta HA interval $>-10$ ms occurred only in atypical AVNRT. This technique, however, requires an ability to record both anterograde and retrograde His bundle depolarization. Tai et al. (8) found that a difference in the VA interval during tachycardia and ventricular pacing $>90$ ms differentiated all patients with AVNRT from those with ORT.

Ormaexte et al. (9) showed that the presence of ventricular fusion with resetting or entrainment of tachycardia occurred in all patients with ORT using a septal accessory pathway and in none of the patients with AVNRT. Martinez-Alday et al. (10) found that a difference in VA intervals $>10$ ms by RV pacing between the apical and posterobasal locations distinguished concealed posteroseptal pathways from AV node pathways, but this criterion could not be applied to anteroseptal accessory pathways. The use of parahisian pacing (11) and the pre-excitation index (12) are other useful methods that may help distinguish a retrograde AV node pathway from a septal accessory pathway.

No previous studies have included patients with posteroseptal pathways that were successfully ablated from the mitral annulus. In this study, 11 patients had posteroseptal accessory pathways that were successfully ablated along the mitral valve annulus.

**Potential pitfalls.** The TCL and VA interval are often perturbed for a few cycles after entrainment. For this reason, care should be taken not to measure unstable intervals immediately after ventricular pacing. In addition, spontaneous oscillation in TCLs and VA intervals may be seen. The discriminant points chosen in this study may not apply when the spontaneous variability is $>30$ ms, which was the maximal variability in cycle length among the tachycardias in this study. Also, it is possible to mistake isorhythmic VA dissociation for entrainment if the pacing train is not long.
enough or the pacing cycle length is too slow. Finally, the criteria may not apply to accessory pathways with significant decremental properties, although small decremental intervals are unlikely to provide a false result.

**Study limitations.** In this study, only cases in which conventional criteria were adequate for diagnosis were included, and ambiguous cases were excluded. Therefore, it is not known how well the criteria tested in this study would perform in cases in which the tachycardia mechanism was ambiguous, based on conventional criteria. In addition, the criteria have not been validated in a prospective fashion.

**Conclusions.** In patients with a long RP supraventricular tachycardia, several criteria are available for distinguishing atrial tachycardia from atypical AVNRT and ORT. Variable RP intervals, different atrial activation sequences during tachycardia and during ventricular pacing and an “AAV” response to ventricular pacing during tachycardia all strongly suggest atrial tachycardia. Relatively fixed RP intervals, the same activation sequences during tachycardia and during ventricular pacing, an AV response to ventricular pacing and termination of the tachycardia by ventricular pacing without depolarization of the atrium strongly suggest atypical AVNRT or ORT. Distinguishing atypical AVNRT from ORT is often straightforward, because an eccentric atrial activation sequence strongly favors ORT. However, distinguishing atypical AVNRT from ORT using a septal accessory pathway may be more problematic, because a concentric atrial activation sequence is present in both. The conventional criteria for differentiating the two forms of tachycardia consist of AV block during tachycardia, which rules out ORT, and an increase in the VA time during functional bundle branch block, which is specific for ORT. Resetting of tachycardia by premature ventricular depolarization and simultaneous His bundle refractoriness strongly favors ORT. Termination of tachycardia with His-refractory premature ventricular depolarization proves accessory pathway participation in re-entrant tachycardia.

Because these conventional criteria are specific but not highly sensitive, there has been a need for additional criteria to distinguish atypical AVNRT from ORT using a septal accessory pathway. These have included the delta AH and delta HA intervals, as well as other techniques described earlier. The results of this study demonstrate two additional criteria for distinguishing AVNRT from ORT using a septal accessory pathway: the difference between the S-A interval and VA interval and the difference between the PPI and TCL. These new criteria can be applied whenever RV pacing during supraventricular tachycardia with concentric atrial activation results in entrainment and is quick, simple to perform and easy to interpret. The PPI–TCL may give enhanced diagnostic sensitivity and specificity, because it accounts for anterograde and retrograde conduction in the tachycardia circuit and, unlike the previous studies mentioned earlier, has the added advantage of excluding atrial tachycardia as a mechanism by the presence of an AV response.

**REFERENCES**