Premature Atrial Complex With P'R Prolongation Indicates Multiple Atrioventricular Nodal Pathways

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Background The goal of the present study was to test if ambulatory Holter recordings can predict the electrophysiologic study (EPS) findings in patients with supraventricular tachycardia (SVT).

Methods and Results The study involved 110 patients with SVT who underwent Holter recording, and then EPS. The hypotheses were that (1) a P'R interval of premature atrial complexes (PACs) between 280 and 400 ms in the Holter recordings predicted dual atrioventricular nodal (AVN) pathways, (2) P'R interval >400 ms predicted triple or more AVN pathways, and (3) SVT initiated by a single PAC suggested easy SVT induction during the EPS. The EPS revealed dual AVN pathways in 14 (93%) of 15 patients with P'R intervals between 280 and 400 ms on the Holter recordings, and triple or more AVN pathways in 18 (90%) of 20 patients with P'R intervals >400 ms. In addition, a single extrastimulus easily induced SVT during the EPS in 11 (85%) of 13 patients in whom SVT was initiated by a single PAC during Holter recording.

Conclusion The ambulatory Holter recording criteria specifically predicted the EPS findings, thereby providing useful advance information. (Circ J 2005; 69: 1233–1236)

Key Words: Ambulatory Holter recording; Electrophysiologic study; Multiple atrioventricular nodal pathways; Supraventricular tachycardia

Many previous studies have shown not only 2 but also 3 or more atrioventricular nodal (AVN) pathways as part of the reentrant circuit of AVN reentrant tachycardia (AVNRT).^{1–6} Moreover, AV reciprocating tachycardia (AVRT) involving these multiple AVN pathways as the descending limb of the reentrant circuit has been observed.⁷ Although these multiple AVN pathways have been diagnosed only by electrophysiologic study (EPS), ambulatory Holter recording, which is usually performed before invasive testing, may provide some relevant information. To examine whether this is so, we studied the relationship between preceding ambulatory Holter recordings and the EPS findings in patients with supraventricular tachycardia (SVT).

Methods

Study Population

From December 1993 to September 2002, 110 patients (54 men, 56 women, aged 55±16 years) with SVT (56 patients with AVNRT, 54 patients with AVRT) underwent an EPS with preceding ambulatory Holter recording. Thirty-five of these patients had manifest Wolff-Parkinson-White (WPW) syndrome during normal sinus rhythm. All patients gave informed consent before the EPS.

Definition of Multiple AVN Pathways

In our previous EPS of multiple AVN pathways, we showed that the atrio-His (AH) intervals differ between the

fast, intermediate, and slow pathways and that the conduction time through each pathway varies within almost constant ranges independent of the basic cycle length.⁸ In that study, the AH conduction times through the fast, intermediate, and slow AVN pathways were <240 ms, between 240 ms and 360 ms, and >360 ms at cycle lengths of both 600 and 400 ms. We applied those results to the present ambulatory Holter recordings with a roughly estimated P-atrial electrogram interval of 40 ms. Using the longest P'R interval of the premature atrial complex (PAC) in each patient, we defined the fast, intermediate, and slow AVN pathways in the ambulatory Holter recordings as follows: (1) P'R interval between 280 ms and 400 ms represents the existence of dual AVN pathways (fast and intermediate pathways), and (2) P'R interval >400 ms represents the existence of triple or more AVN pathways (fast, intermediate, and slow pathways). All P'R intervals with narrow QRS complexes during the ambulatory Holter recordings were measured manually at a paper speed of 25 mm/s, and the longest P'R interval was determined in each patient.

A conventional EPS was performed when multiple AVN pathways were confirmed by the following criteria: (1) the presence of discrete discontinuities in the AVN conduction curve with sudden jumps of at least 50 ms with a 10-ms decrease in the coupling interval using up to triple atrial extrastimuli, and/or (2) the presence of spontaneous transformation between the intermediate-fast, slow-fast, and slow-intermediate forms of AVNRT.³ In patients with AVRT, the electrophysiologic characteristics of the AV node were determined after catheter ablation of the accessory pathways. We also determined the induction pattern of SVT and analyzed the relationship between the initiation pattern observed in the ambulatory Holter recordings and that observed in the EPS.

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Table 1 Ambulatory Holter Recording and Electrophysiologic Study Findings

	AVNRT (n=56)	AVRT (n=54)	Total (n=110)
<i>Ambulatory Holter recording</i>			
P'R interval between 280 ms and 400 ms	12	3	15
P'R interval more than 400 ms	20	0	20
SVT initiated by a single PAC	8	5	13
<i>Electrophysiologic study</i>			
Dual AVN pathways	21	15	36
Triple or more AVN pathways	35	0	35
SVT induced by single atrial extrastimulus	28	34	62

AVNRT, atrioventricular nodal reentrant tachycardia; AVRT, atrioventricular reciprocating tachycardia; SVT, supraventricular tachycardia; PAC, premature atrial complex; AVN, atrioventricular node.

Statistical Analysis

Sensitivity, specificity, and positive and negative predictive values were calculated by the conventional method⁹ for the Holter recordings criteria in relation to the EPS findings.

Results

Ambulatory Holter Recordings (Table 1)

In the preceding ambulatory Holter recordings, the patients had $741 \pm 3,921$ PACs/day (from 1 to 39,422 PACs/day). Whereas SVT of more than 3 beats was observed in 66 patients (60%) in the ambulatory Holter recordings, clinical spontaneous SVT lasting 30 s or more was observed in 23 patients (20.9%). All P'R intervals were less than 600 ms. The longest P'R interval was between 280 ms and 400 ms (Fig 1A) in 15 patients (13.6%) and >400 ms (Fig 1B) in 20 patients (18.2%). SVT was initiated by a single PAC (Fig 1C,D) in 13 patients (11.8%).

EPS (Table 1)

Dual but not triple AVN pathways were confirmed in 36 patients (32.7%, 21 with AVNRT and 15 with AVRT). The triple or more AVN pathways were observed in 35 patients (31.8%), all of whom had AVNRT. SVT was induced by a single atrial extrastimulus in 62 patients (56.3%).

Relationship Between the Ambulatory Holter Recordings and the EPS Findings

The appearance of a P'R interval between 280 ms and 400 ms during the ambulatory Holter recordings was strongly associated with existence of dual AVN pathways: the EPS conformed dual AVN pathways in 14 of 15 patients (93.3%) with these PACs, whereas dual AVN pathways existed in 22 of 95 patients (23.2%) without a P'R interval between 280 ms and 400 ms. A P'R interval >400 ms well predicted the existence of triple or more AVN pathways: the EPS revealed triple or more AVN pathways in 18 of 20 patients (90%) with these PACs, compared with 17 of 90 patients (18.9%) without a P'R interval >400 ms. Moreover, the SVT initiation pattern during the ambulatory Holter recordings associated well with the EPS findings: of the 13 patients in whom SVT was spontaneously initiated by a single PAC during ambulatory Holter recording, 11 (84.6%) showed SVT induced by a single atrial extrastimulus during the EPS.

The specificity and sensitivity of the ambulatory Holter recording criteria are shown in Table 2. When limited to patients without manifest WPW syndrome, the specificities of these criteria regarding P'R interval were not affected:

98% for dual and 97% for triple or more AVN pathways. Although their sensitivities were relatively low, our 3 parameters were highly specific, predictive of the results of the EPS, irrespective of the existence of manifest WPW syndrome.

Discussion

Although ambulatory Holter recordings are useful for identifying various types of arrhythmias,¹⁰ evaluation of the AVN characteristics is usually done by an invasive EPS. However, based on our evaluation of the relationship between the ambulatory Holter recordings and the EPS findings, we have shown that ambulatory Holter recording is also useful for investigating the AVN. The appearance of prolonged P'R intervals in the ambulatory Holter recordings well predicts the characteristics of AVN conduction manifested in the EPS.

Multiple AVN pathways are proven by the presence of 2 or 3 discrete discontinuities in the AVN conduction curve generated during an EPS and are known to exist in 5–10% of patients with SVT.^{1–3} In the present study, we observed triple or more AVN pathways in 31.8% of patients, a slightly higher percentage than expected. However, because we constructed AV conduction curves using up to 3 atrial extrastimuli, the results are thought to be quite accurate. In addition, spontaneous transformation between the intermediate–fast, slow–fast, and slow–intermediate forms of AVNRT was included.

In the EPS, atrial extrastimuli are introduced with varying coupling intervals at fixed basic cycle lengths, whereas in ambulatory Holter recording, the PAC occurs with varying coupling intervals at various cycle lengths of sinus rhythm. It might seem as though the conditions cannot be compared, but the P'R interval is known to be affected mainly by the basic cycle length and also by the coupling interval of the PAC. However, in the present analysis, we emphasized the zone of the longest P'R interval. Our previous study confirmed that the conduction times through the AVN pathways are dependent on the basic cycle length and the coupling intervals of the extrastimuli, but that the AH intervals through each pathway can vary within almost constant ranges independent of the basic cycle length and the coupling interval.⁸ Therefore, we hypothesized that the longest P'R interval would predict the existence of multiple AVN pathways and our study revealed that the ambulatory Holter recordings could predict the AVN characteristics observed in the subsequent EPS with high specificity.

In addition to the characteristics of AVN conduction, we

Fig 1. (A) Representative ambulatory Holter recording of a P-R interval of premature atrial complex (PAC) between 280 ms and 400 ms. In this case, the P-R interval of the PAC was 320 ms, predictive of dual atrioventricular nodal (AVN) pathways. (B) Representative ambulatory Holter recording of a P-R interval of PAC of more than 400 ms. In this case, the P-R interval of PAC was 480 ms, predictive of triple or more AVN pathways. (C) Representative ambulatory Holter recording of initiation of atrioventricular reciprocating tachycardia by a single PAC with a P-R interval of 200 ms. Retrograde P waves were observed in the ST segments, suggesting the existence of concealed accessory pathways. (D) Representative ambulatory Holter recording of initiation of AVN reentrant tachycardia by a single PAC with a P-R interval of 400 ms, suggesting the existence of triple AVN pathways.

Table 2 Relationship Between Ambulatory Holter Recording and Electrophysiologic Study Findings

Ambulatory Holter recording	Electrophysiologic study	Specificity (%)	Sensitivity (%)	PPV (%)	NPV (%)
P-R interval between 280 ms and 400 ms	Dual AVN pathways	98	39	93	76
P-R interval >400 ms	≥triple or more AVN pathways	97	51	90	81
SVT initiated by a single PAC	SVT induced by a single atrial extrastimulus	96	18	85	47

PPV, positive predictive value; NPV, negative predictive value. All other abbreviations, see Table 1.

were able to predict the induction pattern of SVT in the EPS on the basis of the ambulatory Holter recordings. In most patients with SVT initiated by a single PAC during ambulatory Holter recording, a single atrial extrastimulus also induced tachycardia in the EPS, as expected. However, we do not fully understand the relationship between the 2 events. Feasibility of SVT induction in the EPS depends on several factors: the refractory periods of the antegrade and retrograde limbs and the conduction time through the AVN, all of which would be affected by the basic cycle length, the coupling intervals of the extrastimuli, and the autonomic nervous system. Because the ambulatory Holter recordings do not well reflect these important factors individually, the observed relationship should be indirect. In patients with inducible SVT, SVT might occur frequently during daily life, thus increasing the chances of catching an episode during ambulatory Holter recording. Therefore, it should be noted that SVT initiated by a single PAC in the ambulatory Holter recordings may not be a good marker for predicting the feasibility of SVT induction compared with predicting the presence of multiple AVN pathways based on the P'R interval.

Study Limitations

First, because the ambulatory Holter recordings are electrocardiograms recorded during daily life, noise can not be avoided completely. Moreover, it would be difficult to determine the P'R intervals of occasional low amplitude P waves. We had to omit the recordings with much noise and/or extremely low amplitude P waves and thus the sensitivity of the specific findings was decreased. Second, in 35 patients with manifest WPW syndrome, P'R intervals with pre-excitation were excluded. Our criteria for the P'R intervals can be applied only to narrow QRS complexes. Third, the sensitivity of our findings was quite low; however, this limitation is intrinsic to ambulatory Holter recording itself.¹ Similarly, ambulatory Holter recordings without PAC and SVT could never be useful, a limitation

of non-invasive testing. Nevertheless, we believe ambulatory Holter recordings can aid in the assessment of AVN characteristics in SVT patients.

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