Detection of Concealed Left Sided Accessory Atrioventricular Pathway by P Wave Signal Averaged Electrocardiogram

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Objectives. The purpose of this study was to examine whether P wave signal-averaged electrocardiogram (P-SAECG), which detects subtle changes in P wave, detects the concealed accessory atrioventricular pathway (AP).

Background. It is difficult to differentiate atrioventricular reciprocating tachycardia (AVRT) due to the AP from atrioventricular nodal reentrant tachycardia (AVNRT) when the ventricular preexcitation is absent on 12-lead electrocardiograms. By electrophysiological studies, the anterograde conduction in the concealed AP is shown to be blocked near the AP-ventricular interface during sinus rhythm.

Methods. P-SAECG during sinus rhythm was performed in 20 normal volunteers (control), 21 patients with AVRT due to the concealed AP, 19 with AVNRT, 22 with paroxysmal atrial fibrillation (PAF), and 7 with automatic atrial tachycardia (AT). The filtered P wave duration (FPD) and AR20 (power spectrum area ratio of 0–20 to 20–100 Hz) were measured and repeated in AVRT, AVNRT and AT groups at one week after catheter ablation.

Results. The anterograde conduction in the concealed left-sided AP was confirmed in all cases by an electrophysiological study. The FPD in AVRT group was more prolonged than that in controls or AVNRT group. Although the FPD was similar between AVRT and PAF groups, AR20 differentiated between the two groups. Ablation of the concealed AP shortened FPD in AVRT group but that of the slow pathway or the atrial focus did not shorten in the AVNRT or AT groups, respectively. The changes in FPD after ablation were correlated with those in the duration of atrial activity by an electrophysiological study (r = 0.67).

Conclusions. Our findings suggest that P-SAECG detects the concealed left-sided AP, providing a clinical tool in noninvasively assessing atrial activation patterns.

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The common form of paroxysmal supraventricular tachycardia is either atrioventricular reciprocating tachycardia (AVRT) due to the accessory atrioventricular pathway (AP) or atrioventricular nodal reentrant tachycardia (AVNRT) due to dual atrioventricular nodal pathways (1–5). It is clinically important to diagnose whether paroxysmal supraventricular tachycardia is due to the conduction through a reentrant circuit comprising either the AP or dual atrioventricular nodal pathways because of the differences in therapeutic strategies (4–6). However, when the ventricular preexcitation through the AP is absent on standard electrocardiograms, it is difficult to noninvasively detect the AP during sinus rhythm.

In the previous anatomical studies, most APs have been shown to course through the subepicardial fat pad around the mitral annulus and to connect the epicardial surface of the left atrium to that of the left ventricle (11–14). The AP through which impulses conduct only in the retrograde direction is generally called the concealed AP (7,15). Recently, electrophysiological studies have demonstrated that anterograde conduction in the concealed AP is present and blocked at or near the AP-ventricular interface during sinus rhythm (16–22), suggesting that an atrial impulse conducts until the AP-ventricular interfaces through the concealed AP.

The P wave signal-averaged electrocardiogram (P-SAECG) has been clinically applied to atrial arrhythmias. The P-SAECG can detect the subtle abnormalities of intraatrial conduction. Recent clinical studies by others (23–26) and us (27) demonstrated a prolonged filtered P wave duration (FPD) by the time domain analysis in patients with a paroxysmal atrial fibrillation (PAF). Therefore, we hypothesized that in patients with the concealed AP, the activation potential of anterograde conduction in the concealed AP may prolong the terminal section of atrial activation, which may prolong FPD obtained by the P-SAECG. Accordingly, the purpose of the present study was to test whether P-SAECG is useful to detect the presence of the concealed AP in patients with a history of supraventricular tachycardia with narrow QRS configurations.

Methods

Study subjects. Eighty-nine subjects were enrolled in this study (Table 1). No patients had any evidence of ventricular
Abbreviations and Acronyms

AP = accessory atrioventricular pathway
AVNRT = atrioventricular nodal reentrant tachycardia
AVRT = atrioventricular reciprocating tachycardia
AT = atrial tachycardia
FPD = filtered P wave duration
PAF = paroxysmal atrial fibrillation
P-SAECG = P wave signal-averaged electrocardiogram

preexcitation (delta wave) on 12-lead standard electrocardiogram and Holter monitoring. Twenty-one patients had documented AVRT with the concealed AP and without a PAF. They were 16 to 72 years old. Nineteen patients had documented AVNRT with dual atrioventricular nodal pathways and without a PAF. They were 15 to 67 years old. Twenty-two patients had documented symptomatic PAF. They were 40 to 60 years old. Seven patients had documented symptomatic automatic atrial tachycardia (AT). They were 20 to 59 years old. Twenty healthy volunteers, who were matched with the other four study groups for age and sex, served as a control group. They were 26 to 60 years old. No subjects had coexistent organic heart diseases as assessed by two dimensional echocardiography and cardiac catheterization. Clinical characteristics were similar among the five groups for the sex distribution, age, cardiothoracic ratio on chest x-rays, and dimension of cardiac chambers and ejection fraction measured by echocardiography. All arrhythmic agents were discontinued ≥5 half-lives before the study. Written informed consent was obtained from all subjects. This study was approved by the ethical committee of human investigations in our institution.

P-SAECG. According to the previous method (27), recordings were made in a shielded room to minimize noise. For the P-SAECG recording, we used a multi-purpose electrocardiograph (VCM-3000, Fukuda Denshi Co., Tokyo, Japan) and a micro-potential preamplifier (VL-303, Fukuda Denshi Co., Tokyo, Japan). Ag/AgCl electrodes were placed on the chest of each resting subject who lay on the back. The signal-averaged electrocardiogram was recorded from a modified X, Y, and Z lead system, which was developed for P wave signal averaging as well as for conventional R wave-triggered signal averaging (28). The X lead was between the right and left shoulders, similar to the standard I lead. The aVF lead was used as the Y lead. The Z lead was positioned on the precordial center line in the fifth intercostal space. For the recording, we amplified by 1000 times the potential signals derived through these X, Y, and Z leads. Input signals were sampled at 1 kHz and A/D converted in 12 bits. All signal data were identified by the P wave template-matching method. P wave-triggered signals of 250 beats during sinus rhythm, excluding supraventricular premature contractions, were integrated without filtering (23,27). After the 250 beats integration, the noise level was lower than 1 μV. The acquired data were stored on a floppy disk and analyzed using a personal computer (PC-9821, NEC Co., Tokyo, Japan).

Time and frequency domain analysis. For time domain analysis, averaged P wave triggered signals were filtered through a band-pass filter of 40–300 Hz with use of a Butterworth filter according to the conventional method (23,27). A spatial vector magnitude electrocardiogram was compiled with X, Y, and Z leads (23,27). With the use of a computer graphic cursor, the onset and offset of P wave were defined as the point at which the voltage of the atrial signal exceeded 1 μV in the TP segment and returned to the 1 μV level, respectively (27). With this method, we were able to measure changes of the P wave by 1 ms. A representative recording is shown in Fig. 1A. For frequency domain analysis, the method of processing was designed to give a power spectrum of the whole P wave. The start and end points of P wave obtained from signal-averaging were identified with the use of a computer graphic cursor on the basis of the standard electrocardiographic criteria as previously described by us (27). Fast Fourier Transform analysis with Blackmann–Harris four-term window (29) was performed in the lead Z. As shown in Fig. 1B, AR20 (i.e., the power spectrum area in the 0–20 Hz zone divided by that in the 20–100 Hz zone) was calculated. The FPD and AR20 were measured in all subjects and repeated in AVRT and AVNRT groups at one week after radiofrequency catheter ablation. To assess the effect of atrial ablation on the P-SAECG, the FPD and AR20 were also measured in patients with AT without accessory pathway before, and one week after, catheter ablation.

Electrophysiological study. In 58 patients with a documented paroxysmal supraventricular tachycardia without apparent ventricular preexcitation on standard electrocardiograms, an electrophysiological study was performed with local anesthesia. Briefly, three 6F quadrupolar electrode catheters (RESPONSE, Daig Co., Minnetonka, Minnesota) were advanced to the high right atrium, his bundle, and right ventricular apex. A 6F octopolar electrode catheter (RESPONSE, Daig Co., Minnetonka, Minnesota) was advanced to the coronary sinus. Sustained supraventricular tachycardia was induced by programmed stimulation and the presence of mechanisms with AVRT or AVNRT was defined by standard

Table 1. Clinical Characteristics of Study Subjects

<table>
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<th>Control (n = 20)</th>
<th>AVNRT (n = 19)</th>
<th>AVRT (n = 21)</th>
<th>PAF (n = 22)</th>
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<td>Male/female</td>
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<td>47 ± 4</td>
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<tr>
<td>LVDs (mm)</td>
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<td>32 ± 6</td>
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<td>EF (%)</td>
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<td>72 ± 7</td>
<td>73 ± 7</td>
<td>71 ± 7</td>
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Data are presented mean value ± SD or number of patients. AVNRT = atrioventricular nodal reentrant tachycardia; AT = atrial tachycardia; PAF = paroxysmal atrial fibrillation; AVRT = atrioventricular reciprocating tachycardia; CTR = cardiothoracic ratio; LAD = left atrial dimension; LVDd = left ventricular end-diastolic dimension; LVDs = left ventricular end-systolic dimension; EF = ejection fraction.
techniques (10,30,31). In this study, 34 patients had AVRT (right-sided AP in 2 and left-sided AP in 32) and the remaining 24 did AVNRT. In these patients with AVRT or AVNRT, we excluded patients with a history of PAF from this study. As a result, 25 patients had AVRT (left-sided AP in all) and 23 had AVNRT. Furthermore, we confirmed that patients with AVRT did not have latent preexcitation by coronary sinus pacing near the accessory pathway or administration of intravenous injection of adenosine (20 mg, one bolus) (32). Next, programmed electrical stimulation using eight basic stimuli \( S_1 \) at a cycle length of 600 ms followed by single extrastimulus \( S_2 \) was delivered at the high right atrium. The \( S_1S_2 \) interval was shortened by 10 ms until it reached the effective refractory period of the right atrium. \( A_1 \) and \( A_2 \) referred to the atrial activity resulting from \( S_1 \) and \( S_2 \), respectively. To exclude patients with a substrate for PAF, which affects the P-SAECG, the following exclusion criteria were adopted: 1) when the \( S_2-A_2 \) interval exceeded the \( S_1-A_1 \) interval more than 50 ms on the His bundle electrogram (33,34); 2) when the difference between durations of \( A_2 \) and \( A_1 \) is exceeded by more than 70 ms on the high right atrial electrogram (35); and 3) when two or more atrial responses with a return cycle <300 ms occurred (36,37). According to these criteria, 4 patients with AVRT and 4 with AVNRT were excluded. Consequently, 21 patients with AVRT and 19 with AVNRT were enrolled in this study.

In accordance with the previous method by Suzuki et al. (18,22), we assessed the anterograde conduction in the concealed AP in AVRT. First, the retrograde effective refractory period of the concealed AP was measured by the right ventricle basic drive followed by single ventricular extrastimulation (conventional ventricular extrastimulus method). Second, the retrograde effective refractory period of the concealed AP was measured by the simultaneous basic drive of the right ventricle and the high right atrium or the coronary sinus followed by single ventricular extrastimulation (simultaneous atrioventricular method). The anterograde conduction in the concealed AP was considered to be present if the retrograde effective refractory period obtained from the simultaneous atrioventricular method was 10 ms or more shorter than that obtained from the conventional ventricular extrastimulus method (18).

**Radiofrequency catheter ablation procedure.** For AVRT. After confirming the presence of anterograde conduction in the concealed AP, radiofrequency catheter ablation with an electrical mapping method was performed with the retrograde aortic approach. Briefly, a 7F deflectable tip catheter (Mansfield, Webster Co., Watertown, Massachusetts), was introduced via the femoral artery and positioned under or above the mitral valve annulus. Radiofrequency energy (500 kHz; NL50-1, Central Industry) was delivered through the distal electrode at 20 watts during right ventricular pacing. When the retrograde AP conduction was lost within 10 s, the application of radiofrequency energy at 20 watts was maintained for 30 s. Before and after ablation during sinus rhythm, the atrial activity on the ablation site was recorded at a paper speed of 100 mm/s by the distal bipolar electrodes of the ablation catheter, with a center-to-center interelectrode distance of 2 mm, using a filter bandwidth of 30 to 500 Hz (CATHCOR, Siemens) and then the duration of the atrial activity was measured. The duration of the atrial activity was defined as the time from the beginning of the earliest electrical activity that deviated from the stable baseline value to the last point of the atrial electrogram at which the baseline value was crossed. At 30 min after the final application of radiofrequency energy, the effects of ablation were assessed. The ablation was considered...
successful if the retrograde AP conduction was no longer present by ventricular pacing before and after administration of both intravenous injection of atropine (1 mg, one bolus) and intravenously continuous infusion of isoproterenol (0.02 µg/min/kg).

For AVNRT. After the mechanism of tachycardia had been determined to be AVNRT, radiofrequency catheter ablation was performed with the anatomic and/or electrical mapping approach. As described above, the same deflectable tip catheter was introduced via the femoral vein and used for ablation of the slow pathway with a delivery of radiofrequency energy at 20 watts for 10 s. When junctional ectopic beats occurred during the delivery of radiofrequency energy, radiofrequency energy at 20 watts was delivered for more than 20 s. At 30 min after the final application of radiofrequency energy, the ablation procedure was considered successful if AVNRT could no longer be induced by atrial and ventricular programmed pacing before and after both intravenous injection of atropine and infusion of isoproterenol.

For AT. After tachycardia was diagnosed to be automatic AT by standard techniques (38,39), radiofrequency catheter ablation was performed with the electrical mapping approach. As described above, the same deflectable tip catheter was introduced via the femoral vein and used for ablation of the tachycardia focus with a delivery of radiofrequency energy at 20 watts for 10 s. When the tachycardia was terminated, radiofrequency energy at 20 watts was delivered for more than 20 s. The ablation procedure was considered successful if AT could no longer be induced by intravenous infusion of isoproterenol 30 min after the final application of radiofrequency energy.

Statistical analysis. Data are presented as mean value ± SD. Statistical differences were determined by the Student’s t test for paired data before and after radiofrequency catheter ablation and by the Fisher’s exact probability test for data between groups. Multiple comparisons were examined by repeated measures ANOVA with a post hoc Scheffé test. The correlation between the changes in FPD and the duration of atrial activity was compared by linear regression analysis. The sensitivity, specificity and predictive accuracy were calculated with parameters of FPD and AR20 at various cut points in order to detect AVRT before ablation. Differences were considered statistically significant when p was less than 0.05.

Results

Anterograde conduction in concealed AP in AVRT. The location of all concealed APs was left-sided (left posterior area in 5, left lateral area in 10, left anterolateral area in 5 and left anterior area in 1). The retrograde effective refractory period of the concealed AP obtained from the simultaneous atrioventricular extrastimulus method (256 ± 33 ms) was significantly shorter than that obtained from the conventional ventricular extrastimulus method (297 ± 36 ms) in each subject. Differences in the retrograde effective refractory period of concealed APs obtained from these two different methods were −40 ±

22 ms (−15 to −110 ms), indicating the presence of antero-
grade conduction in the concealed AP in all cases of AVRT.

P-SAECG. In the time domain analysis (Fig. 2A), the FPD in patients with AVRT was significantly longer than that in controls and patients with AVNRT. The FPD was similar between patients with AVRT and PAF. Filtered P wave duration was significantly longer in AVRT than in controls and AVNRT, but was similar between AVRT and PAF. AR20 was not different between in AVNRT and AVRT, but was significantly greater in PAF than in AVRT.

Figure 2. Pooled data of the filtered P wave duration (panel A) by the time domain analysis and AR20 (panel B) by the frequency domain analysis in controls, and patients with AVNRT, AVRT or PAF. Filtered P wave duration was significantly longer in AVRT than in controls and AVNRT, but was similar between AVRT and PAF. AR20 was not different between in AVNRT and AVRT, but was significantly greater in PAF than in AVRT.
anterior area (n = 1) 142 ms and 1.1, respectively. Statistical analyses of FPD and AR20 among the four AP areas could not be carried out because of the small number of patients. Figure 3 shows the representative recordings of FPD before and after ablation in two patients of AVRT. Figure 4 shows pooled data of FPD and AR20 before and after ablation in patients with AVNRT, AVRT and AT. Ablation significantly shortened FPD in patients with AVRT (from 130 ± 8 to 122 ± 5 ms, p < 0.0001) but did not in patients with AVNRT and AT. Ablation did not significantly affect AR20 in any of them. Both FPD and AR20 after ablation were also similar among patients with AVRT, AVNRT and AT.

In patients with AVRT, the averaged changes in FPD after ablation by catheters placed above (n = 8) and under (n = 13) the mitral valve were 9.6 ± 5.2 and 7.5 ± 5.1 ms, respectively. Two different catheter ablation techniques did not differ in terms of the averaged changes in FPD.

Duration of atrial activity at the ablation site. Figure 5 shows pooled data of the duration of atrial activity in patients with AVRT, which were significantly shortened from 62 ± 19 to 52 ± 17 ms (p < 0.0001) after successful ablation. In these patients, a total of 48 applications of radiofrequency energy before successful ablation did not shorten the duration of atrial activity (from 55 ± 12 to 54 ± 12 ms, p = NS). As shown in Fig. 6, there was a significant correlation between the changes in FPD and those in the duration of atrial activity after ablation in patients with AVRT (r = 0.67, p < 0.001).

P wave duration on standard electrocardiogram. The P wave durations in lead II, III, aVF and V1 were similar among the four groups before ablation and they did not change after ablation (Table 2).

Sensitivity and specificity for AVRT. When FPD > 125 ms was used, the sensitivity, specificity, positive predictive accuracy, and negative predictive accuracy were 71%, 67%, 43%, and 87%, respectively. When FPD > 125 ms and AR20 < 2.0 were combined, the sensitivity, specificity, positive predictive accuracy, and negative predictive accuracy were 48%, 100%, 100%, and 85%, respectively (Table 3).

Discussion

The most important findings of the present study are: 1) the filtered P wave duration, FPD, on P-SAECG was longer in patients with AVRT than in patients with AVNRT or controls; 2) AR20 was significantly smaller in patients with AVRT than in those with PAF, although FPD was similar between them; 3) after radiofrequency catheter ablation, FPD was shortened in patients with AVRT but not in patients with AVNRT; and 4) the changes in FPD after ablation were correlated with those in the duration of atrial activity obtained by electrophysiological studies. Thus, with combined time and frequency domain analyses we may be able to noninvasively detect anterograde conduction in the concealed AP and to differentiate AVRT.

Figure 3. Representative recordings of filtered P wave duration obtained from two patients with the concealed accessory atrioventricular pathway before and after radiofrequency catheter ablation.
from AVNRT. Furthermore, after successful ablation, P-SAECG indicated the disappearance of anterograde conduction in the concealed AP.

**Diagnosis of concealed AP.** In this study, all patients with AVRT or AVNRT had tachycardia with narrow QRS configurations. It is usually difficult to clinically differentiate AVRT from AVNRT as it was in our cases. We confirmed the diagnosis of concealed AP by the following electrophysiological findings. First, we detected during supraventricular tachycardia that the earliest retrograde atrial activation was in the left atrial free wall in all patients with AVRT, but that was in the low anterior septum in patients with AVNRT (10,30,31). Second, we did not detect ventricular preexcitation (delta wave) during decremental or premature atrial pacing (10) and during coronary sinus pacing near the accessory pathway or by the administration of intravenous injection of adenosine (20 mg, one bolus) (32). Of course, the patients with AVNRT did not have any evidence of concealed APs.

**Prolonged FPD in AVRT.** Concealed anterograde conduction into an accessory atroventricular pathway is a well-demonstrated phenomenon during electrophysiological study (16–22). In the present study, we confirmed anterograde conduction in the concealed AP by the following electrophysiological findings. We determined the presence of anterograde conduction in the concealed AP by demonstrating the peeling back phenomenon (18). If the anterograde conduction in the concealed AP is present, the refractoriness of the concealed AP is peeled back by the anterograde conduction of the basic atrial impulse during the simultaneous atrioventricular pacing, which makes the subsequent ventricular extra impulse in the earlier phase conduct to the atrium (18). Thus, the effective refractory period measured by the simultaneous atiroventricular pacing method becomes shorter than that measured by conventional ventricular extrastimulus method. Suzuki et al. (18) has reported the differences in the retrograde effective refractory period of the concealed AP to be $-51 \pm 30$ ms between the simultaneous atiroventricular and conventional ventricular extrastimulus methods. Our values were $-40 \pm 22$ ms, similar to those reported by Suzuki et al. Clinical characteristics including age, sex distribution, and other cardiovascular diseases in this study did not differ from those in the Suzuki’s study. Although we confirmed the anterograde conduction of the concealed AP in our patients with AVRT by demonstrating the peeling back phenomenon, we did not know reasons for the small difference between the two studies. The FPD was significantly prolonged in patients with AVRT com-

**Figure 5.** Pooled data of the duration of atrial activity at the ablation site in patients with AVRT. Ablation significantly shortened the duration of atrial activity.
pared to controls and patients with AVNRT, and there was a clear distinction between patients with AVRT and AVNRT as well as controls. Because no patients had organic heart disease, and cardiac dimensions and ejection fraction were similar among these three groups, this prolongation of FPD was not due to organic changes of the heart, especially the left atrium. It was not due to supraventricular tachycardia per se, because the FPD was similar between controls and patients with AVNRT. Thus, it is assumed that the prolonged FPD may result from the activation potential of anterograde conduction in the concealed AP.

To further examine this issue, we measured the duration of atrial activity during the electrophysiological study before and after ablation and calculated changes in the duration of atrial activity after ablation. Successful ablation significantly shortened the duration of atrial activity and the FPD in patients with AVRT, whereas unsuccessful ablation did not change the duration of atrial activity. Accordingly, the shortening of the duration of atrial activity was caused by the ablation of the concealed AP but not caused by ablation per se. Furthermore, we compared changes in the duration of atrial activity with changes in FPD after ablation. Changes in those were significantly correlated. Ablation of the slow pathway in AVNRT did not alter FPD, suggesting that slow pathway conduction does not affect FPD. One possible explanation may be due to the difference in the structural location between left-sided APs and slow pathways because the left-sided APs are at the epicardial location, whereas the slow pathway is at the interior location (3,11–14). This possibility may be also implicated for the right-sided and septal APs which were not studied in this study. Furthermore, the changes in FPD did not differ among ablations of atrial and ventricular insertion sites. In patients with AT, atrial ablation did not affect parameters of FPD and AR20. Thus, the shortening of the FPD was caused by the ablation of the concealed AP but not caused by ablation per se. Taken together, our results suggest that the prolonged FPD in patients with AVRT is caused by the activation of anterograde conduction in the concealed AP.

**AVRT versus PAF.** In AVRT, we excluded patients with a substrate for PAF. As shown in Fig. 2A, measurements of FPD did not differentiate patients with AVRT from those with PAF. The FPD was prolonged in both groups. The prolonged FPD in patients with PAF is well known (23–27). The mean FPD in patients with PAF was 134 ± 8 ms in this study, similar to 137 ± 14 ms reported by Fukunami et al. (23), 135 ± 8 ms reported by Stafford et al. (24) and 133 ± 20 ms reported by us (27). To further differentiate patients with AVRT from those with PAF on P-SAECG, we analyzed the frequency component of the whole P wave. We have previously demonstrated that AR20, the power spectrum area in the 0–20 Hz zone divided by that in the 20–100 Hz zone, was significantly greater in patients with PAF than in controls, indicating increased high frequency components in PAF. In this study, AR20 was greater in PAF than in controls as reported previously (27). Moreover, AR20 was greater in patients with PAF than in those with AVRT. Thus, we were able to differentiate AVRT from PAF with AR20 even though FPD was similar between these two groups. Although it was not the purpose of this study to elucidate mechanisms underlying the difference of AR20 between PAF and AVRT, it is probably due to different activations of the atrium; in PAF the activation of the whole P wave is electrophysiologically abnormal and in AVRT only the terminal section of the P wave may be abnormal because of the anterograde conduction through the concealed AP.

**Sensitivity and specificity.** Although there was clear distinction of FPD between AVRT and AVNRT; the specificity and positive predictive accuracy to detect AVRT was not so high because there was a significant overlap of FPD between AVRT and PAF. When the combination of FPD > 125 ms and AR20 < 2.0 was used, they became 100%. Therefore, the criteria of both FPD > 125 ms and AR20 < 2.0 have to be fulfilled to detect AVRT when PAF was not excluded.

**Limitations of the study.** Several limitations of the present study may be considered. First, we studied only left-sided APs including free wall APs but not right-sided and septal APs. Thus, our findings may not be directly applicable to right-sided and septal APs. However, our findings in this study still have clinical relevance because right-sided and septal APs are much less frequent than left-sided APs (1,6,7,15,20). Second, we excluded patients with a substrate for PAF according to the exclusion criteria by electrophysiological study in this study. Accordingly, these exclusion criteria may have excluded patients with atrial conduction abnormality in and around the atrial insertion site of the concealed AP that may promote

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### Table 2. P Wave Duration on Standard Electrocardiogram

<table>
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<tr>
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<th>Control (n = 20)</th>
<th>AVNRT (n = 19)</th>
<th>AVRT (n = 21) Before</th>
<th>AVRT (n = 21) After</th>
<th>PAF (n = 22)</th>
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<td>Lead II (ms)</td>
<td>101 ± 9</td>
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<td>101 ± 6</td>
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<td>103 ± 12</td>
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<td>Lead III (ms)</td>
<td>101 ± 11</td>
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<td>102 ± 10</td>
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<td>Lead aVF (ms)</td>
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<td>Lead V1 (ms)</td>
<td>100 ± 11</td>
<td>95 ± 7</td>
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<td>97 ± 11</td>
<td>96 ± 10</td>
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</table>

Data are presented mean value ± SD. Abbreviations are as same shown in Table 1.

### Table 3. Sensitivity, Specificity and Predictive Accuracy of P-SAECG for AVRT

| FPD > 120 ms | 86 | 39 | 33 | 89 |
| FPD > 125 ms | 71 | 67 | 43 | 87 |
| FPD > 130 ms | 52 | 79 | 46 | 83 |
| FPD > 125 ms and AR20 < 2.0 | 48 | 100 | 100 | 85 |
| FPD > 125 ms and AR20 < 2.5 | 67 | 90 | 70 | 89 |
| FPD > 125 ms and AR20 < 3.0 | 71 | 80 | 56 | 89 |

FPD = filtered P wave duration; AR20 = power spectrum area ratio of 0–20 to 20–100 Hz.
PAF. This may have resulted in the decrease in the number of patients with AVRT and limited the clinical use of the P-SAECG. In this regard, a prospective study with the P-SAECG is necessary for the differential diagnosis of paroxysmal supraventricular tachycardia in patients in whom PAF was not excluded. Finally, we confirmed anterograde conduction in the concealed AP by the Suzuki et al. method. The results obtained from this method may represent the peeling back of accessory pathway refractoriness or that of atrial refractoriness, although it is unlikely to be able to differentiate them.

Conclusions. The present study, to the best of our knowledge, provides the first demonstration that P-SAECG using the combination of time and frequency domain analyses is noninvasively capable of detecting the anterograde conduction in concealed AP and useful for differentiating AVRT from AVNRT during sinus rhythm. Thus, P-SAECG may provide the validity as a research and clinical tool to accurately describe atrial activation patterns.

References