Non-Invasive Diagnosis of Concealed Wolff-Parkinson-White Syndrome by Detection of Concealed Anterograde Pre-Excitation

Takao Katoh, MD; Toshihiko Ohara, MD; Eung Moon Kim, MD; Hirokazu Hayakawa, MD

Electrophysiological findings suggest that concealed anterograde conduction through accessory pathways may exist even during sinus rhythm in patients with so-called concealed Wolff-Parkinson-White (WPW) syndrome. To evaluate the pre-excitation characteristics in various types of WPW syndrome, high-resolution electrocardiograms were analyzed in 81 consecutive WPW syndrome patients and 50 age-matched normal subjects. The WPW group consisted of 30 cases of concealed WPW diagnosed by electrophysiological study, 38 cases of manifest WPW in which apparent delta waves were constant, and 13 cases of intermittent WPW in which the delta waves appeared periodically. The duration of the low-amplitude, high-frequency components of the signal-averaged filtered QRS complex that preceded the earliest upstroke of the surface QRS, including any delta waves (preceding potential duration, PPD), and the duration of low amplitude signals less than 10μV (I-LAS10) or 20μV (I-LAS20) were measured as parameters of pre-excitation. The PPDs in concealed and intermittent WPW were both significantly longer than in manifest WPW or in control subjects (6.8±2.7 ms, 7.9±3.5 ms vs 2.3±3.2 ms, 1.0±1.6 ms, both p<0.0001). Abnormally prolonged PPDs (>4 ms) were observed in 90% of concealed WPW cases and 76.9% of intermittent WPW, but in only 4% of normal subjects and 31.6% of manifest WPW. Both I-LAS10 and I-LAS20 in the 3 types of WPW syndrome were significantly longer than in normal subjects. The initial portion of the filtered QRS in concealed WPW closely resembled that of intermittent WPW. These results strongly suggest that in concealed WPW anterograde conduction through accessory pathways does occur and produces small amounts of pre-excitation even during sinus rhythm. The study concluded that, despite its name, concealed WPW is not completely concealed, and that non-invasive diagnosis during sinus rhythm is possible by using high-resolution electrocardiography to detect the concealed anterograde pre-excitation. (Jpn Circ J 2001; 65: 367 – 370)

Key Words: Concealed pre-excitation; High-resolution electrocardiography; Non-invasive diagnosis; Wolff-Parkinson-White syndrome

In patients with concealed Wolff-Parkinson-White (WPW) syndrome, no pre-excitation ventricular activity, including delta waves, can be detected with 12-lead surface electrocardiography (ECG) during sinus rhythm, even if those patients have typical episodes of atrioventricular reciprocating tachycardia.1,2 Thus, the diagnosis of concealed WPW syndrome has only been able to be made by the detection of retrograde conduction from the ventricle to the atrium through accessory pathways during an electrophysiological study (EPS).3,4 Recent electrophysiological investigations using programmed electrical stimulation with simultaneous atrioventricular pacing have suggested that concealed anterograde conduction through accessory pathways may occur during sinus rhythm, even in concealed WPW syndrome.5–10 If any evidence of this conduction could be detected on the surface ECG, the diagnosis of concealed WPW syndrome could be made non-invasively and instantaneously during sinus rhythm, which would contribute greatly to the differential diagnosis and therapy of patients who complain of recurrent palpitations.1,12

The purpose of the present study was, therefore, to first evaluate the characteristics of anterograde pre-excitation in patients with various types of WPW syndrome using high-resolution signal-averaged electrocardiography, and then to discuss whether or not non-invasive diagnosis of concealed WPW syndrome is possible.

Methods

Patients

Eighty-one consecutive patients with WPW syndrome and 50 age-matched control subjects with no evidence of pre-excitation on their 12-lead ECG and no history of tachycardia episodes were enrolled. The WPW patients comprised 30 cases of concealed WPW syndrome that had been diagnosed by EPS, 38 cases of manifest WPW syndrome with constant typical delta waves on the surface ECG, and 13 cases of intermittent WPW syndrome in which delta waves appeared periodically on the surface ECG.

High-Resolution Electrocardiography

All the high-resolution ECG were recorded during regular
sinus rhythm with a normal heart rate following 10 min of bed rest. In patients with intermittent WPW syndrome, the ECG was recorded when no delta waves were present.

Signal processor models 7T-18 and DP-1100 (NEC, Nippon Electric Co, Ltd), were used for high-resolution ECG with signal-averaging. X, Y and Z orthogonal leads were used to construct a vector magnitude ECG for evaluating electrical activity around the upstroke of QRS. More than 200 cardiac cycles were averaged on each occasion with an R trigger in order to obtain clear recordings with sufficiently low noise levels (<0.1 µV). After passing through a digital band-pass filter with corner frequencies of 50 and 250 Hz, the following 3 parameters were measured automatically from each recording (Fig 1).

*Preceded Potential Duration (PPD)*  
PPD is the duration of the low-amplitude, high-frequency components of the signal-averaged filtered QRS complex that preceded the earliest upstroke of the surface QRS, including any delta waves present.

*Initial Low-Amplitude Signal Duration Less Than 10 µV (I-LAS10)*  
I-LAS10 is the duration from the onset of low-amplitude signal to the point where the amplitude first reached the 10-µV level in the initial portion of the signal-averaged filtered QRS complex.

*Initial Low-Amplitude Signal Duration Less Than 20 µV (I-LAS20)*  
I-LAS20 is the duration from the onset of low-amplitude signal to the point where the amplitude first reached the 20-µV level in the initial portion of the signal-averaged filtered QRS complex.

The earliest upstroke of the surface QRS and the onset of the signal-averaged filtered QRS were determined as the first point that reached twice the noise level after the end of P wave.

**Statistical Analysis**

All measured data were expressed as mean ± standard deviation. The t-test and the chi-square test were used for the statistical analysis, and p<0.05 was adopted as the level of significance.

**Results**

**Characteristics of the QRS Morphology of High-Resolution Electrocardiograms**

Representative high-resolution ECGs are shown in Fig 2. The upstroke of the signal-averaged filtered QRS in control subjects was rapid and sharp, and both I-LAS10 and I-LAS20 should be very small. In addition, the timing of the onset of the surface QRS and filtered QRS were almost identical, resulting in a PPD of zero or a very low value in most of the control subjects. At the beginning of the filtered QRS in patients with manifest WPW syndrome (Fig 2D), slow continuous signals of low amplitude were seen concurrently with delta waves on the surface ECG. In contrast, patients with intermittent or concealed WPW syndrome who did not have pre-excitation potentials in their surface ECGs, had small, crescent-shaped upstrokes that obviously preceded the signals at the beginning of the filtered QRS and before the onset of the surface QRS (Fig 2B,C), which may have resulted in the prolongation of PPD, I-LAS10 and I-LAS20.

![Fig 1. Automatic measurement of PPD, I-LAS10, and I-LAS20.](image1)

![Fig 2. Representative recordings of high resolution electrocardiogram in a normal subject and patients with various types of WPW syndrome. (A) Normal subject, (B) intermittent WPW syndrome, (C) concealed WPW syndrome, (D) manifest WPW syndrome.](image2)

![Fig 3. Comparison of PPD.](image3)
PPD

PPDs in patients with concealed or intermittent WPW syndrome were significantly longer than in those with manifest WPW or in the control subjects (7.9±3.5 ms, 6.8±2.7 vs 2.3±3.2 ms, and 1.0±1.6 ms, respectively; both p<0.0001) (Fig 3). Because most of the control subjects had a PPD of zero, we regarded PPD values from 0 to 4 (mean +2SD) as the normal range. Abnormally prolonged PPDs were frequently seen in 76.9% (10/13) of cases of intermittent WPW and 90% (27/30) of concealed WPW patients, whereas only 2 normal subjects (4%) and 12 manifest WPW patients (31.6%) exhibited abnormal prolongation of PPD. These differences were statistically significant (p<0.05).

I-LAS10 and I-LAS20

Both I-LAS10 and I-LAS20 were significantly longer in patients with WPW syndrome than in the normal subjects (Figs 4,5). In particular, both parameters in manifest WPW patients were almost 3 times the value of those recorded for the normal subjects (42.3±16.4 vs 13.2±4.7 ms for I-LAS10; 61.9±19.4 vs 23.0±7.6 ms for I-LAS20, both p<0.0001). No differences in the 2 parameters were observed between cases of concealed and intermittent WPW, but these values were both significantly longer than those of the normal subjects (20.6±8.5 ms, 21.3±7.5 vs 13.2±4.7 ms for I-LAS10, both p<0.0001; 30.5±7.7 ms, 32.5±9.0 vs 23.0±7.6 ms for I-LAS20, p<0.0001 and p<0.005, respectively).

Discussion

Prolongation of PPD

PPD is the difference between the upstroke of the QRS of the surface ECG, which has a wide-frequency band-pass filter, and that of the signal-averaged filtered ECG, which has a selected high-frequency band-pass filter. PPD was zero in most of the normal subjects, whereas there were small but significant prolongations of PPD in patients with concealed or intermittent WPW syndrome. Thus, the prolongation of PPD indicates that a certain amount of pre-excitation with high-frequency components of the ventricle is present much earlier than the onset of the surface QRS. If this is true, why is pre-excitation activity not seen in the surface ECG? It is possible that the amount of pre-excitation ventricular activity in patients with concealed or intermittent WPW syndrome is too small or too partial to be reflected on the surface ECG. In manifest WPW syndrome, on the other hand, ample pre-excitation of the ventricle took place and appeared as delta waves on the surface ECG, resulting in very low PPD values.

Concealed Anterograde Conduction Through an Accessory Pathway

Suzuki et al have reported that concealed anterograde conduction through an accessory pathway may occur even in patients with concealed WPW syndrome. Through induction by simultaneous programmed atrioventricular stimulation, they revealed a shortening of the retrograde refractory period via the accessory pathway, which suggested that a ‘peeling back’ phenomenon caused by concealed anterograde conduction had been detected. The small amount of pre-excitation observed in the patients with concealed WPW syndrome in the present study can be induced by this concealed anterograde conduction through the accessory pathways.

The reason that the pre-excitation is so slight and has been concealed is somewhat difficult to explain clearly. Usually anterograde conduction through an accessory pathway produces full pre-excitation, resulting in the formation of a typical delta wave, as in manifest WPW syndrome. However, there must be a decremental property in the pre-excited area of the ventricular muscle in concealed WPW syndrome, as suggested by Kuck et al and Gonzales et al. Our results also suggest the possibility of this characteristic, because of the similarity to intermittent WPW syndrome where anterograde conduction activity must surely be taking place through the accessory pathways, but is sometimes blocked or somehow disappears on the way to the ventricle.

Prolongation of I-LAS

Recently, Yoshida et al reported that the duration of the filtered P wave was prolonged in patients with concealed WPW syndrome. They also suggested that this prolongation was related to concealed anterograde conduction through an accessory pathway. However, if such concealed conduction produces pre-excitation, the pre-excited area must be in the ventricle, because the exit of the accessory pathways is connected to the ventricular tissue. Also, in general, these accessory pathways have to be electrically shielded until their exit. We therefore hypothesized that pre-excitation activity must appear just prior to ventricular excitation, if present, and we investigated the upstroke of the QRS with the R-triggered signal-averaged ECG. In our study, significant prolongation of both I-LAS was observed in all types of WPW syndrome whether the delta wave was...
overt or not. Thus, the prolongation of I-LAS simply indicates the presence of pre-excitation of the ventricle. The values of the I-LAS parameters in manifest WPW patients who showed apparent delta waves on their surface ECGs were almost 3 times that of normal subjects, and in the cases of concealed and intermittent WPW, the values were 50% greater than in the normal subjects. These differences of I-LAS among the various types of WPW syndrome may reflect differences in the expansion of the pre-excited area; in other words, full pre-excitation or partial pre-excitation.

Characteristics of Anterograde Conduction Through an Accessory Pathway

As a summary of the results of the present study, manifest WPW patients showed minimal PPD with great prolongation of the I-LASs, whereas concealed and intermittent WPW patients had a long PPD with moderate prolongation of the I-LASs. The nature of the initial portion of the filtered QRS in concealed WPW was very similar to that in intermittent WPW. These results strongly suggest that, in patients with concealed WPW syndrome who do not show any delta wave on the surface ECG, there is anterograde conduction through accessory pathways, which produce small amounts of pre-excitation even during sinus rhythm; however, its impulse propagation breaks down on en route to the ventricle.

Conclusion

So-called concealed WPW syndrome is not completely concealed and non-invasive diagnosis during sinus rhythm is possible by detecting the concealed anterograde pre-excitation on high resolution electrocardiography.

References