Demonstration of Two Anomalous Bypasses in Concealed Wolff-Parkinson-White Syndrome*

Kazumasa Hiejima, M.D.; Shutaro Satake, M.D.; Yasuki Sakamoto, M.D.; Fumio Suzuki, M.D.; and Toyomi Sano, M.D.

Two patients with a history of paroxysmal supraventricular tachycardia but no evidence of the Wolff-Parkinson-White syndrome in the conventional electrocardiograms were studied utilizing atrial and ventricular extrastimuli. The evidence obtained in these patients was consistent with a concealed Wolff-Parkinson-White syndrome. In one patient, ventricular extrastimuli revealed three different responses in the curve of ventriculoatrial conduction, depending upon the interval of stimulus. In the other patient, intracardiac recordings, including the left atrial potential, showed that paroxysmal supraventricular tachycardia was induced by an impulse via an anomalous bypass which diverged from the main bypass or stemmed independently from the left ventricle and was maintained by impulses via the main bypass which lay between the left ventricle and the left atrium. The mechanisms for initiation of the paroxysmal supraventricular tachycardia were discussed.

Recent electrophysiologic studies have demonstrated the presence of an anomalous bypass capable only of retrograde conduction.1,2 This phenomenon has been termed retrograde Wolff-Parkinson-White syndrome3 or concealed Wolff-Parkinson-White syndrome.4 On the other hand, the presence of bilateral anomalous bypasses has been demonstrated anatomically4 and electrophysiologically.5,6

In this report, we present the results of an electrophysiologic study in two patients without evidence of Wolff-Parkinson-White syndrome in the conventional electrocardiograms, in which the presence of bilateral anomalous bypasses in one case and the presence of two anomalous bypasses in the same side of the heart in the other were indicated.

MATERIALS AND METHODS

Electrophysiologic studies were performed utilizing incremental and extrastimulus techniques with simultaneous electrocardiographic and His bundle recordings.7,8 Stimuli were delivered by a programmable digital pulse generator with a stimulus-isolation unit (San-Ei Sokki 3F-36).

A1 and H1 were the atrial and His bundle electrograms of the basic atrial driving impulse. A2 and H2 were the atrial and His bundle electrograms of the atrial testing impulse. V1 and V2 were the ventricular electrograms of the basic atrial or ventricular driving impulse and the atrial or ventricular testing impulse, respectively. A1' and A2' were the retrograde atrial electrograms of the basic ventricular driving impulse and the ventricular testing impulse, respectively.

The functional refractory period and the effective refractory period of the atrioventricular node or the His-Purkinje system were defined as previously described by Wit et al.9

RESULTS

CASE 1

The patient was a 41-year-old man who had recurring attacks of paroxysmal supraventricular tachycardia. The resting ECGs always showed normal P-R intervals and narrow QRS complexes. Electrophysiologic studies were performed twice within a six-month period. The results are shown in Table 1.

Right atrial pacing in the first study at rates of 80 to 180 impulses per minute showed the usual increase in the atrio-His (A-H) interval and a constant His-ventricle (H-V) interval. Atrioventricular block did not occur at these rates.

Paroxysmal supraventricular tachycardia was consistently elicited at the critical prolongation of H-V intervals during pacing and sinus rhythm and not, however, at A-H intervals. Figure 1 shows a representative tracing in which paroxysmal supraventricular tachycardia was induced by a premature atrial impulse during sinus rhythm. The impulse was aberrantly conducted to the ventricles and was associated with a prolongation of the H-V interval (60 msec), showing a pattern of left bundle-branch block. Narrowing of the QRS complex occurred at

*From the First Department of Internal Medicine and the Institute for Cardiovascular Diseases, Tokyo Medical and Dental University, Tokyo, Japan.
Manuscript received October 12; revision accepted December 3.
Reprint requests: Dr. Hiejima, 5-45 Yushima, 1-chome, Bunkyo-ku, Tokyo Medical and Dental University, Tokyo, Japan.

CHEST, 72: 2, AUGUST, 1977
the fifth beat of the paroxysmal supraventricular tachycardia. At this beat the interval between stimulus and low atrial potential (V-A' interval) shortened from 195 to 135 msec, accompanied by shortening of the H-V interval to its control values. These findings suggest that the His-Purkinje system is an essential link in the circuit of reentry.

With right ventricular pacing at rates of 110 to 190 impulses per minute, the V-A' interval was increased only by 10 msec. Figure 2 shows a V-A' conduction curve in which the responses of the V2-A2' interval are plotted against the V1-V2 coupling intervals. Three different responses of V2-A2' intervals were observed: (1) no increase in the V2-A2' interval between 690 to 460 msec of V1-V2 intervals; (2) the usual increase between 450 to 390 msec; and (3) no increase between 370 to 280 msec. The refractory period of the ventricular myocardium was reached at a V1-V2 interval of 270 msec.

In this study, it was observed that when 2:1 A-H block was induced by atrial pacing at a rate of 190 impulses per minute, conducted beats showed only transiently a Wolff-Parkinson-White pattern (Fig 3). The configuration of those preexcitation beats was consistent with that of type B. Except for this, the Wolff-Parkinson-White pattern was not observed over several manipulations, including atrial extrastimulus.

**Interpretation.** Ventricular stimulation revealed that two retrogradely anomalous bypasses possessing different properties were present (the first anomalous bypass was of the longer effective refractory period and the second was of the shorter effective refractory period). Namely, the effective refractory periods of the first and second anomalous bypasses were 460 msec and less than 270 msec, respectively. The mode of onset of paroxysmal supraventricular tachycardia showed that a retrograde impulse was transmitted through the second anomalous bypass to the atrium (Fig 2). Because of the longer refractory period of the left bundle branch, an atrial impulse given at the critical coupling intervals found the left bundle branch refractory and was conducted to the ventricles only via the right

---

**Figure 1.** Paroxysmal supraventricular tachycardia induced by atrial premature impulse during sinus rhythm (case 1). Numbers shown are in milliseconds. From top to bottom, tracings are: high right atrial electrogram (HRA), His bundle electrogram (HBE), and electrocardiographic leads, V1 and 2 (II). A' signifies retrogradely depolarized low atrial potential. Times lines are at 250-msec intervals, and paper speed is 100 mm/sec. Note that length of cycle of paroxysmal supraventricular tachycardia shortened from 390 to 305 msec.

**Figure 2.** Curve of V-A' conduction constructed by method of ventricular extrastimulus (case 1). Length of cardiac cycle (CL) is 690 msec. There are different responses followed by echo beats.
bundle branch during its relative refractory period. Then, the impulses invaded the left bundle branch retrogradely and, in turn, were transmitted to the left atrium via a left-sided bypass. Repeated retrograde invasion of the left bundle branch by the preceding impulses left it refractory to the next antegrade impulses, and then the pattern of left bundle-branch block persisted. During paroxysmal supraventricular tachycardia showing a pattern of left bundle-branch block, the H-V interval was prolonged, suggesting an increase in the refractoriness of both bundle branches. At the fifth beat of the paroxysmal supraventricular tachycardia, an antegrade impulse was transmitted to the left bundle branch, which now became nonrefractory, and back to the atrium directly via the bypass. This assumption explains why the prolongation of the H-V interval was necessary and why the cycle length of the paroxysmal supraventricular tachycardia was shorter during normal intraventricular conduction (305 msec) than with left bundle-branch block (390 msec).

The Wolff-Parkinson-White pattern consistent with type B in this patient suggests the presence of a right-sided bypass. Since the location of the second anomalous bypass was considered to be left-sided, the first anomalous bypass seemed most likely to be localized in the right side of the heart.

In summary, this patient seemed to possess two bilateral bypasses, i.e., one bypass capable of bidirectional conduction on the right side, although its function for antegrade conduction was inferior, and another bypass capable only of retrograde conduction on the left side of the heart.

Table 1—Results of Electrophysiologic Studies in Two Patients

<table>
<thead>
<tr>
<th>Data</th>
<th>Case 1 (M, 41 yr)</th>
<th>Case 2 (M, 26 yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study 1</td>
<td>Study 2</td>
</tr>
<tr>
<td>Sinus rhythm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-A interval, msec</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>A-H interval, msec</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>H-V interval, msec</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Length of cardiac cycle, msec</td>
<td>790</td>
<td>820</td>
</tr>
<tr>
<td>Atioventricular node</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional refractory period, msec</td>
<td>360</td>
<td>400</td>
</tr>
<tr>
<td>Effective refractory period, msec</td>
<td>&lt;250</td>
<td>350</td>
</tr>
<tr>
<td>His-Purkinje system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional refractory period, msec</td>
<td>430</td>
<td>&lt;400</td>
</tr>
<tr>
<td>Effective refractory period, msec</td>
<td>390</td>
<td>&lt;350</td>
</tr>
<tr>
<td>Atrial refractory period, msec</td>
<td>250</td>
<td>260</td>
</tr>
<tr>
<td>Echo zone, msec</td>
<td>390-360</td>
<td>Only 360</td>
</tr>
</tbody>
</table>
Case 2

The patient was a 28-year-old man with recurrent paroxysmal supraventricular tachycardia and mitral stenosis. The resting ECGs of the patient showed no evidence of either a Wolff-Parkinson-White syndrome or any other forms of preexcitation. Electrophysiologic studies were performed before and after cardiac surgery (Table 1).

Before surgery, rapid atrial pacing at rates of 90 to 200 impulses per minute revealed the usual prolongation of the A-H interval, resulting in Wenckebach’s A-H block at a rate of 220/min. Paroxysmal supraventricular tachycardia was consistently elicited by atrial testing impulses given at critical coupling intervals. The echo zone was 320 to 250 msec at the basic cycle length of 610 msec. Ventricular extrastimulus, at the cycle length of 610 msec, did not increase the time of V-A’ conduction until a V1-V2 interval of 300 msec. At this V1-V2 interval, paroxysmal supraventricular tachycardia was induced. At V1-V2 intervals between 290 to 230 msec, the time of V-A’ conduction was progressively prolonged, and consequently paroxysmal supraventricular tachycardia was induced. The refractory period of the ventricular myocardium was reached at a V1-V2 interval of 220 msec.

Because the presence of an anomalous bypass capable only of retrograde conduction was considered in these findings, epicardial mapping was attempted during the cardiac surgery. When the apex of the right ventricle was stimulated, the earliest activation was recorded on the posterior wall of the left atrium. Then, after the mitral commissurotomy an area of the left atrium above the attachment of anteromedial and posterolateral leaflets around the posterolateral commissure and parallel to the atrioventricular ring was cut by about 5 cm in length.

After surgery the patient twice experienced short episodes of palpitation. The results of the second electrophysiologic study were similar to the results of the first, suggesting that the bypass was not completely severed; however, at this time, a lower left atrial potential was simultaneously recorded from the coronary sinus. Figure 4 shows the findings dur-

![Figure 4](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/20996/)

Figure 4. Mode of onset of paroxysmal supraventricular tachycardia (case 2). Length of cardiac cycle is 500 msec. CS signifies left atrial electrogram (LA) recorded in coronary sinus. Panel A, Control tracing. Note that left atrial electrogram precedes right atrial deflection (A’) during retrograde conduction. At V1-V2 interval of 250 msec, V2 is conducted to both atria with same time interval as that of V1. Two consecutive beats following A2’ appear prematurely, suggesting intraatrial reentry. Panel B, Representative tracing. At V1-V2 interval of 200 msec, V2 is not conducted to both atria; however, paroxysmal supraventricular tachycardia does occur. Same deflection as occurs during paroxysmal tachycardia following this V2 shows that V2 is conducted antegradely to His bundle after having once returned somewhere distal to His bundle. Length of cycle of paroxysmal supraventricular tachycardia is about 300 msec. Times lines are at 200 msec intervals, and paper speed is 100 mm/sec. HRA, High right atrial electrogram; and HBE, His bundle electrogram.
ing the ventricular extrastimulus. Panel A illustrates a control tracing. A left atrial deflection (LA in Fig 4A) in the coronary sinus precedes that from the right atrium (A’). This suggests that retrograde conduction occurred through the left atrium, as evidenced by epicardial mapping. Following two ectopic beats (intra-atrial reentry?), a sinus beat appears, which is associated with the H-V interval of 40 msec (indicated by an arrow, Fig 4A). Paroxysmal supraventricular tachycardia was induced at V1-V2 intervals between 250 to 190 msec. Panel B of Figure 4 illustrates a representative record. It is noteworthy that the paroxysmal supraventricular tachycardia was induced without depolarization of both atria. Figure 4B shows that antegrade conduction occurred through the His bundle because a distinct deflection of the His bundle potential precedes a V wave with the same H-V interval as those during the tachycardia. This phenomenon was repeatedly observed at the onset of paroxysmal supraventricular tachycardia.

Interpretation. In this patient the presence of an anomalous retrograde bypass and of a circuit of reentry through the left atrium was demonstrated by electrophysiologic studies and epicardial mapping. It is particularly of interest that the left atrium was not immediately depolarized on the onset of the paroxysmal supraventricular tachycardia. The first ventricular activation following V2 seems unlikely to be a so-called V3 phenomenon, as reported by Akhtar et al,16 because of the following two reasons: (1) the same position and configuration of the H deflection following V2 as those of sinus beats (this being the case, the QRS complex in question had to be associated with H-V intervals which were greater than those of sinus beats because of incomplete recovery of the right bundle branch); and (2) the sudden appearance of the H deflection in association with paroxysmal supraventricular tachycardia (if, however, a V3 phenomenon was present, a V2-H interval would be progressively prolonged as the V1-V3 interval was shortened).

When S2 was given to the ventricles at the S1-S2 interval of 220 msec, A’ was not induced. This means that the refractory period of the left atrium, including an input-area of the bypass, was at least 200 msec. Since the cycle length of the circuit for reentry through the left atrium was 300 msec, this cannot be explained without assuming a shorter pathway or side branch of the previously mentioned bypass which entered the atrioventricular node or an upper part of the His bundle.

In summary, the presence of two anomalous bypasses of different properties was indicated. The main bypass, which was capable only of retrograde conduction, was located between the left ventricle and the left atrium. In addition, another bypass, which diverged from this main bypass or independently stemmed from the left ventricle and entered the atrioventricular node or an upper part of the His bundle was clearly indicated to be present.

Discussion

The term, “concealed Wolff-Parkinson-White syndrome,” can be used when an antegrade anomalous bypass is present without any indications appearing in the conventional surface ECG. The previously mentioned cases seem to be consistent with the Wolff-Parkinson-White syndrome of such a type. In addition, the presence of two anomalous bypasses was considered in both cases. The combination of two anomalous bypasses was suggested electrophysiologically as being “in parallel” (Kent and James bundle or Kent and Mahaim bundle11-18), as well as “in series” (James and Mahaim bundle17); however, the presence of bilateral anomalous bypasses has been suggested electrophysiologically in only two cases to date.5,6 The combination of the anomalous bypasses in our case 1 is very similar to that in the case of Denes et al,6 in which a rightsided bypass was capable of bidirectional conduction and a left-sided bypass was capable only of retrograde conduction; however, these two cases5,6 differ from our case 1 in that resting ECGs of these two cases showed a distinct type-B Wolff-Parkinson-White syndrome. Consequently, our case is consistent with a concealed Wolff-Parkinson-White syndrome and from our knowledge seems to be the first description of its kind, to date.

In our case 1, the reason why the QRS complexes showing Wolff-Parkinson-White syndrome never appeared, except during atrial pacing performed at the time of the second study, is unknown. Svenson et al18 described the following two causes of apparent antegrade block in the bypass: (1) late input into the bypass relative to the normal pathway; and (2) ineffective input into the bypass due presumably to the pattern of atrial activation, resulting in failure of either conduction over or entrance into the bypass. The former cause seems unlikely in our case, because atrial extrastimulus was administered at the same position as an electrode catheter. At any event, the appearance of the Wolff-Parkinson-White pattern when 2:1 atrioventricular block was induced at a rate of 190 impulses per minute suggests that the refractory period of the anomalous bypass is extremely long, as compared with that of the atrioventricular node.

In case 2, a left-sided anomalous bypass capable only of retrograde conduction was demonstrated. It
was assumed that paroxysmal supraventricular tachycardia occurred antegradely through the normal pathway and retrogradely through the anomalous bypass. In addition, it seems most likely that paroxysmal supraventricular tachycardia was initiated by an impulse propagating via a connecting bridge to the atrioventricular node or the upper part of the His bundle. Such a combination of two bypasses also has not been described to date.

REFERENCES