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Clinical and Electrophysiological Characteristics in Korean Patients with WPW Syndrome

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This study was designed to investigate the clinical and electrophysiologic characteristics of WPW syndromes in Korea. A total of 400 symptomatic WPW syndrome patients were consecutively recruited. The most common documented symptomatic tachyarrhythmia was orthodromic atrioventricar reentrant tachycardia (75.3%), followed by atrial fibrillation (31.3%), and antidromic atrioventricular reentrant tachycardia (6.2%). There was a higher incidence of multiple bypass tract in patients with antidromic tachycardia than in those with orthodromic tachycardia (30.4 vs 4.3%, $P<0.001$). The inducibility of tachyarrhythmia with electrophysiologic study in this study population was 95.8%. The most frequent location of the accessory pathway was the left free wall (48.0%), followed by the right free wall (29.1%), posterior septum (17.5%) and anterior septum (3.5%). These results indicated that 1) clinical and electrophysiological characteristics of Korean patients with WPW syndrome were similar to those of western countries and 2) the electrophysiologic study was important in the evaluation of patients with WPW syndrome.

Key Words: WPW syndrome, electrophysiologic study, Korean

Wolff-Parkinson-White (WPW) syndrome was first reported clinically in 1930 by J. Wolff and J. Parkinson in Europe and by P. White in the United States (Wolff *et al.* 1930). In 1967, the mechanism of preexcitation and atrioventricular (AV) conduction via accessory pathway in addition to the normal atrioventricular node was proved electrophysiologically by Durrer and Ross (1967). Although several papers regarding electrophysiologic findings in patients with preexcitation syndrome have been published in the western world (Gallagher *et al.* 1978; Horowitz, 1986), there have been no systematic Korean data related to clinical and electrophysiological findings of preexcitation syndrome (Kim, 1988).

Here, we report the clinical and electrophysiological findings of 400 Korean patients with preexcitation syndrome.

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MATERIALS AND METHODS

We investigated 400 consecutive Korean patients with WPW syndrome from December 1986 to September 1995. Their clinical manifestations and history were recorded completely. Electrocardiographies at the advent of symptoms, including palpitation, dizziness, and loss of consciousness were collected and analyzed as much as possible. Structural

cardiac abnormalities were evaluated by echocardiography, cardiac catheterization, and/or angiogram.

All patients underwent pre-procedural evaluation including routine physical examination, 12-lead electrocardiogram (ECG), chest PA and routine blood chemistry examination. After obtaining informed consent, the complete electrophysiologic study was performed without sedation. All anti-arrhythmic medications were discontinued at least five half-lives before the procedure in all patients. Percutaneous venous access was established via the right and left femoral and left subclavian veins. A modified Seldinger technique was also used for right femoral arterial access for a mapping catheter and for continuous blood pressure monitoring. All patients received 3000 U heparin bolus with an additional 1000 U bolus per hour. Three 5-French quadripolar electrode catheters (Daig Corporation, Minenetonka, MN, USA) with 5 mm interelectrode spacing, were inserted via both the femoral vein and left subclavian vein under fluoroscopic guidance. Also, these catheters were positioned at the high right atrium, His bundle region, and right ventricular apex for local intracardiac electrogram recording and pacing. A 7-French decapolar electrode catheter (Daig Corporation, Minenetonka, MN, USA) was introduced via the left subclavian vein and positioned in the coronary sinus (CS). Five sequential bipolar recordings were obtained from distal to proximal with this decapolar CS catheter. The distance between paired bipoles was 2 mm, and the distance between each bipolar recording pair was 10 mm. The first bipolar pair was the most distal pair and the last bipolar pair was the most proximal pair. The proximal pair of electrodes was positioned at the CS ostium, and the location of the accessory pathway was confirmed by a mapping catheter in all patients. Surface ECG leads (I, aVF, V1), intracardiac electrograms from various sites, and blood pressure were simultaneously displayed on a multichannel monitor and recorded at a paper speed of 100 or 200 mm/sec with VR/6 Electronics for Medicine or Quinton EP Lab System. Oscilloscopic images were recorded by the Quinton EP Lab System. The electrogram signals were filtered at 30 to 500 Hz for conventional mapping. The electrophysiologic study protocol consisted of incremental pacing and premature stimulation of the atrium and ventricle. This protocol allows for evaluation of the antegrade and retrograde AV nodal and accessory pathway conduction properties, and to induce atrioventricular reentrant tachycardia (AVRT). If AVRT were not induced, isoproterenol ($1 \sim 2\ \mu g\ min^{-1}$) was infused to facilitate the induction of AVRT.

The location of the accessory bypass tract was classified as 1) left lateral, 2) left anterior, 3) left

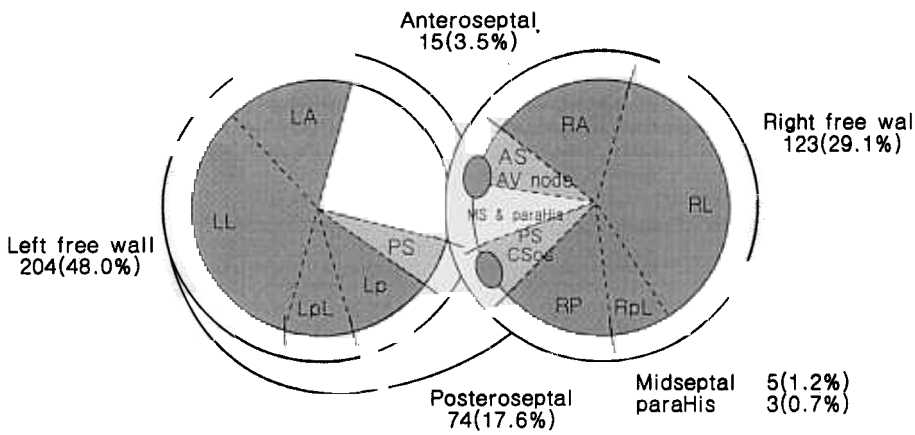

Fig. 1. Classification and distribution of 424 accessory pathways in 400 patients with WPW syndrome. The most common location of accessory pathway was the lateral portion of mitral annulus(left lateral). AVN: AV node, AS: anteroseptal, MS: midseptal, LA: left anterior, LL: left lateral, LP: left posterior, LpL: left posterolateral, paraHis: Para-Hisian, PS: Posteroseptal, RA: right anterior, RL: right lateral, RP: right posterior, RpL: right posterolateral.

posterior, 4) left posterolateral, 5) right anterior, 6) right lateral, 7) right posterolateral, 8) right posterior, 9) posterior septum, 10) anterior septum, and 11) mid-septum and parahisian area (Fig. 1).

Statistical analysis was done with Fisher's exact test using SPSS program.

RESULTS

Clinical manifestations of WPW syndrome

The ages ranged from 3 to 75 yrs old (mean 35±15 yrs). There were 262 men and 138 women. Mean symptom duration was 8.1±7.6 yrs and the frequency of symptoms was mean 4.2±9.8 times/month. The palpitation persisted from 30 minutes to 4 days (Table 1).

Thirty-six patients (9.0%) experienced loss of consciousness resulting from rapid ventricular responses, including 16 cases of atrial fibrillation with rapid ventricular responses. There were two cases of aborted sudden cardiac death. All 18 cases who required direct current cardioversion from hemodynamic instability were related to atrial fibrillation, including three cases aggravated after intravenous administration of verapamil.

The 24 cases of congenital heart disease (8 cases of Ebstein's anomalies; 5 cases of atrial septal defect; 2 cases of persistent left superior vena cava; 2 cases of dextrocardia; 2 cases of corrected transposition of great vessels; 2 cases of hypoplastic coronary sinus; 1 case of double outlet right ventricle; 1 case of ventricular septal defect; and 1 case of cardiac rhabdomyoma) and 13 cases of acquired heart diseases were connected with cardiac abnormalities in this study population (Table 2).

Table 1. Clinical profiles of 400 patients with WPW syndrome at Yonsei Cardiovascular Center (Dec. 1986~Sep. 1995)

Sex	Male	262
	Female	138
Age	Mean(±S.D.)	35±15 years
	Range	3~75 years
Symptoms	Duration	8.1±7.6 years
	Frequency	4.2±9.8 times/month
	Duration of each episode	7.5±4.9 hours/episode
	Syncope(%)	36(9.0%)

Clinically documented tachyarrhythmias

Among 400 patients, electrocardiography at palpitation was collected and evaluated in 368 patients (92.0%), of which orthodromic AVRT was documented in 277 patients (75.3%). Thus, it was the most common tachyarrhythmia in this study population. Of these 277 patients, 43 also showed atrial fibrillation, and one case showed antidromic AVRT as well as atrial fibrillation. Antidromic AVRT was documented in 23 cases (6.2%). There were 69 patients (31.3%) who had only atrial fibrillation documented at the events of palpitation (Table 3, Fig. 2).

Electrophysiologic study

Induced tachyarrhythmias during electrophysiologic study: Among 233 patients who had clinically-documented AVRT, orthodromic tachycardia was repeatedly induced in 221 cases, antidromic tachy-

Table 2. Associated cardiac anomalies in 400 patients with WPW syndrome

Congenital		24
Ebstein's anomaly	8	
ASD	5	
Corrected TGV	2	
Persistent left SVC	2	
Dextrocardia	2	
Hypoplastic CS	2	
VSD	1	
DORV	1	
Rhabdomyoma	1	
Acquired		13
Cardiomyopathy	5	
Hypertrophic		3
Dilated		1
Tachycardia-mediated		1
MS, MR	4	
AR, AS	3	
TR	1	

AR: aortic regurgitation, AS: aortic stenosis, ASD: atrial septal defect, CS: coronary sinus, DORV: double outlet right ventricle, MS: mitral stenosis, MR: mitral regurgitation, TGV: transposition of great vessels, TR: tricuspid regurgitation, SVC: superior vena cava, VSD: ventricular septal defect

cardia was induced in four cases, and atrial fibrillation was induced in 20 cases during electrophysiologic study. However, no tachyarrhythmias were induced in seven patients (3.0%). There were antegrade dual atrioventricular pathways in 10 cases, including three cases with inducible atrioventricular nodal reentrant tachycardia. Among 44 patients who had documented atrial fibrillation as well as orthodromic tachycardia, orthodromic AVRT was induced in 40 patients, including two cases with inducible antidromic AVRT, while atrial fibrillation as well as AVRT were induced in 27 patients. However, atrial fibrillation only was induced in the remaining four patients.

Among 23 patients who had documented antidro-

Table 3. Types of tachyarrhythmias in 368 patients with ECG documentation

Types of tachyarrhymias	No(%)
Orthodromic AVRT	277/368(75.3)
AVRT only	233
With Afib	43
With antidromic AVRT, Afib	1*
Antidromic	23/368(6.2)
Only	20
With Afib	2
With Afib, orthodromic AVRT	1*
Afib†	115/368(31.3)
Only	69

Afib: atrial fibrillation, AVRT: atrioventricular reentrant tachycardia, *: a patient with orthodromic and antidromic AVRT and atrial fibrillation, †: including patients with AVRT

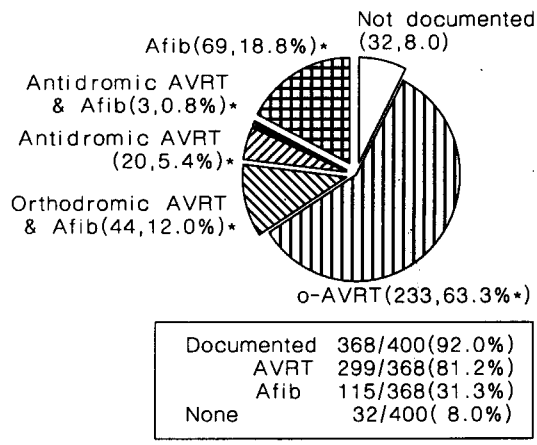

*Fig. 2. Clinically-documented tachyarrhythmias in 400 patients with WPW syndrome. Tachyarrhythmias were documented in 368 patients among 400 patients. Orthodromic AVRT was the most common tachyarrhythmia. Afib: atrial fibrillation, AVRT: atrioventricular reentrant tachycardia. *Proportion among 368 documented tachyarrhythmias.*

Table 4. Induced and clinically documented tachyarrhythmias in 400 patients with WPW syndrome

Induced arrhythmia	Clinically documented arrhythmia							
	AVRT		AVRT with afib			Afib only	Not documented	Total
	Ortho	Anti	Ortho	Anti	Both			
AVRT								
Ortho	203	5	13			18	21	260
Anti	2	3						5
Both	1	8				2		11
Afib								
Only	3		4	1		23	3	34
+Ortho	16		25	1		24		66
+Anti							4	4
+Both	1		1		1			3
Not inducible	7	4				2	4	17
Total	233	20	43	2	1	69	32	400

Afib: atrial fibrillation, Anti: antidromic, AVRT: atrioventricular reentrant tachycardia, Ortho: orthodromic

mic AVRT, orthodromic (65.2%), antidromic (56.0%) AVRT, and atrioventricular tachycardia with atrial fibrillation (13%) were induced in order, but no tachyarrhythmia was induced in the remaining four patients.

Among 69 patients who had documentation of only atrial fibrillation, atrioventricular tachycardia (69.6%), atrial fibrillation with atrioventricular tachycardia (34.8%), and atrial fibrillation only (33.3%) were induced in order, with no inducible arrhythmias in the remaining two patients.

Among 32 symptomatic patients who did not have any documentation of tachyarrhythmias, orthodromic tachycardia (65.6%), antidromic tachycardia (12.5%), and atrial fibrillation (9.4%) were induced in order, but there was no inducible arrhythmia in the remaining 4 patients.

Overall, tachyarrhythmias were inducible in 383 (95.8%) among 400 consecutive symptomatic Korean patients with WPW syndrome (Table 4, Fig. 3).

Location of Accessory Pathways: Among 400 patients, a single bypass tract was identified with electrophysiologic study in 376 patients and multiple bypass tract in 24 (6.0%) patients. The locations of 424 accessory pathways were distributed in the left free wall (48%), right free wall (29.1%), posteroseptum (17.5%), anteroseptum (3.5%), midseptum (1.2%), and parahisian area (0.7%) in order (Table 5, Fig. 1).

Among 24 patients with multiple accessory pathways, the documentation of tachycardias showed 19 cases of AVRT (7 cases of antidromic AVRT, 12 cases of orthodromic AVRT), including five cases associated with atrial fibrillation, and three cases of atrial fibrillation (clinically documented tachyarrhythmias were not available for analysis in two cases).

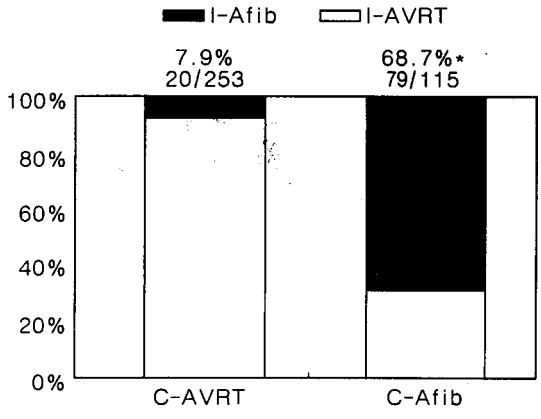

Fig. 3. Relationship between clinically-documented and induced tachyarrhythmias. Atrial fibrillation was more frequently induced during electrophysiologic study in patients with clinically documented atrial fibrillation than it was in those with atrioventricular reentrant tachycardia only. C-Afib: patients with clinically documented atrial fibrillation, C-AVRT: patients with atrioventricular reentrant tachycardia only. I-Afib: induced atrial fibrillation, I-AVRT: induced atrioventricular reentrant tachycardia (Fisher's exact test, $p<0.001$).

Table 5. Location of accessory pathways of 400 patients with WPW syndrome

Site of accessory pathway	Primary	Secondary	Total(%)
Left free wall	196	8	204 (48.0)
Lateral	147	3	150 (35.2)
Posterior and posterolateral	39	5	44 (10.4)
Anterior and anterolateral	10		10 (2.4)
Right free wall	117	6	123 (29.1)
Lateral and posterolateral	52	2	54 (12.8)
Posterior	35	2	37 (8.7)
Anterior	30	2	32 (7.6)
Posteroseptal	69	5	74 (17.5)
Right-sided	59	3	62 (14.7)
Left-sided	10	2	12 (2.8)
Anteroseptal	12	3	15 (3.5)
Midseptal	3	2	5 (1.2)
Para-Hisian	3		3 (0.7)
Total	400	24	424 (100.0)

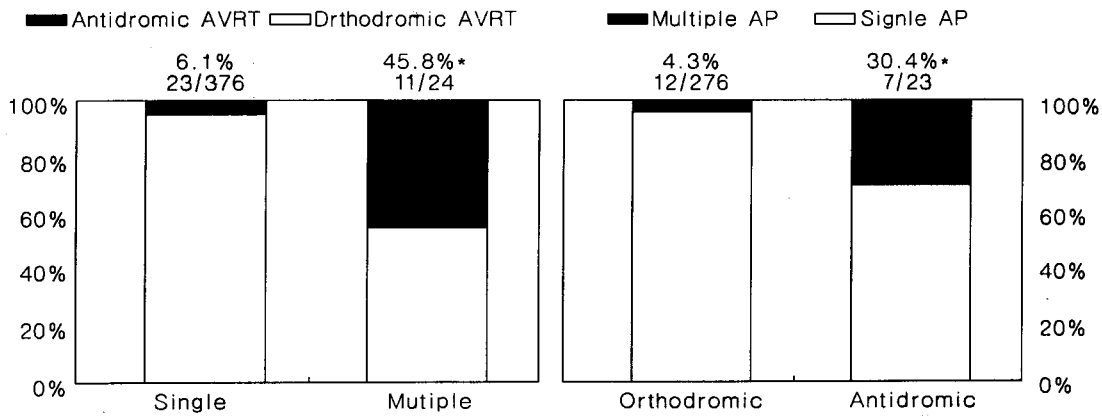

*Fig. 4. Relationship between AVRT mechanism and multiple accessory pathways. Patients with multiple accessory pathways were more likely to have antidromic AVRT (A) than those with a single accessory pathway. Antidromic AVRT was significantly associated with the presence of multiple accessory pathways (B). *: Fisher's exact test, $p<0.001$.*

In the electrophysiologic study, antidromic AVRT was induced in 10 of 24 patients with multiple bypass tracts. Overall of documented tachycardia and induced tachycardia, 11 out of 24 patients with multiple bypass tracts showed antidromic AVRT. Taken together, the incidence of antidromic tachycardia was higher in patients with multiple bypass tract than with single bypass tract (45.8% vs 6.1%, $P<0.001$)(Fig. 4A). In addition, the incidence of multiple bypass tract in antidromic AVRT was significantly higher than in orthodromic AVRT (30.4% vs 4.3%, $P<0.001$)(Fig. 4B).

In eight cases of Ebstein's anomaly, seven cases showed right sided accessory bypass tract. There was one case of multiple bypass tract and also one case of combined AV nodal reentrant tachycardia in patients with Ebstein's anomaly.

DISCUSSION

WPW syndrome is characterized by classical electrocardiographic findings resulting from preexcitation of a part of the ventricular myocardium due to anomalous atrioventricular conduction via an accessory pathway known as the Kent bundle. This connection is made of myocardial fibers which are considered as a congenital abnormality due to the remnants of an atrioventricular connection which was present in the early developmental stages (Klein *et al.* 1980).

Although electrocardiographic abnormalities of the typical ventricular preexcitation are estimated to occur in one-to-three out of every 1000 people, very little is known about the natural history of WPW syndrome (Gallagher *et al.* 1978). The prevalence rate of tachyarrhythmia in patients with WPW syndrome varies from 4.3 to 90% (Neuman *et al.* 1966). The most important clinical manifestation of WPW syndrome is the loss of consciousness and sudden cardiac death resulting from hemodynamic collapse during atrial fibrillation with rapid ventricular response. Due to the absence of decremental conduction properties of the accessory pathway, once atrial fibrillation occurs, rapid impulse of the atrium is conducted to the ventricle directly. Thus, hemodynamic collapse may occur if the heart rate is faster than 200/minute (Klein *et al.* 1979). Klein *et al.* reported that a R-R interval shorter than 250 msec during atrial fibrillation was the most important predictive index for sudden cardiac death in patients with WPW syndrome (Klein *et al.* 1979). In addition, the potential risk of digitalis (Sellers *et al.* 1977) and verapamil, which may facilitate the antegrade conduction properties of an accessory pathway, were emphasized in WPW syndrome. In this study, 16 out of 36 patients with loss of consciousness had atrial fibrillation, and all 18 patients who had DC cardioversion due to hemodynamic instability had atrial fibrillation and rapid ventricular responses. One out of two patients who survived sudden cardiac death experienced ventricular fibrillation after injection of

verapamil for treating atrioventricular tachycardia.

WPW syndrome is associated with various forms of congenital heart disease (Giardina *et al.* 1972). The relations of Ebstein's anomaly (Lev *et al.* 1955) and mitral valve prolapse (Devereux *et al.* 1976) with WPW syndrome have been well established. Among 400 consecutive patients with WPW syndrome in the present study, 24 were found to have congenital heart disease and 13 were associated with acquired heart disease. Similar to the report of Gallagher *et al.* seven out of eight patients with Ebstein's anomaly showed right-sided bypass tract (Gallagher *et al.* 1978).

The most frequently documented tachyarrhythmia in this study was orthodromic atrioventricular tachycardia (75.3%), which was similar to previous reports (Newman *et al.* 1966). Since the two distinct pathways can conduct impulses either from the atrium to ventricle or from the ventricle to atrium, initiation of re-entrant tachycardia requires a unidirectional block in one of two atrioventricular connections. If the AV node has relatively slow conducting properties and the other anomalous accessory pathway has a relatively long refractory period, the properly timed premature atrial beat could exclusively conduct to the ventricle via the AV node, thereby initiating AVRT. The circuit of orthodromic atrioventricular tachycardia is composed of antegrade conduction over the AV node and retrograde conduction via the accessory pathway.

The prevalence of antidromic atrioventricular tachycardia, which utilizes the accessory pathway for antegrade conduction, has been reported in from 7-to-15% of WPW syndrome (Wellens and Brugada, 1984; Colavita *et al.* 1987). The clinical significances of antidromic tachycardia are higher prevalences of dizziness, loss of consciousness, and ventricular fibrillation. The incidence of multiple accessory pathway is also higher in antidromic tachycardia than in orthodromic tachycardia (Atie *et al.* 1990). In this study, seven out of 23 patients with antidromic tachycardia had multiple bypass tract in contrast to 12 out of 276 patients with orthodromic tachycardia.

The prevalence of atrial fibrillation in WPW syndrome has been reported as from 11.5-to-39% (Wellens and Durrer, 1974; Campbell *et al.* 1977). In this study, the incidence of patients with only atrial fibrillation was 18.8%, however, that rose to 31.3% if patients who also had atrioventricular tachycardia as well as atrial fibrillation were added. Bauernfeind *et al.* reported that conversion of atrioventricular tachycardia to atrial fibrillation was more frequently observed in patients who had clinically- documented atrial fibrillation than it was in those who did not have such characteristics (Bauernfeind *et al.* 1981). They also reported that atrioventricular tachycardia can be induced in 77% of those patients. Although atrial fibrillation was not aggressively induced during the electrophysiologic study, atrial fibrillation was inducible in 82 out of 115 patients with clinically-documented atrial fibrillation, compared to 31 out of 253 patients with atrioventricular tachycardia. Furthermore, AVRT was induced in 48 out of 69 patients in whom atrial fibrillation was the only documented arrhythmia.

With electrophysiologic study, tachyarrhythmias were induced in 383 out of 400 patients, including 32 patients who had no documented tachyarrhythmia. Meanwhile, locations of 424 accessory pathways in 400 patients were confirmed. Among them, 48% were located in the left free wall; 29.1% in the right free wall; 17.5% in the posterior septum; 3.5% in the anterior septum; and 1.2% in the mid-septum. Those results were similar to the report of Oren *et al.* (1993).

In conclusion, we observed the clinical and electrophysiological characteristics of 400 consecutive Korean patients with WPW syndrome which were similar to those reported from western countries. In addition, we were successfully able to induce 95.8% of tachyarrhhythmias through electrophysiologic study and could also define the role of electrophysiologic study in the diagnosis and treatment of patients with WPW syndrome.

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