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Effect of atrial pacing on phase analysis in patients with the Wolff-Parkinson-White syndrome

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Summary

Phase analysis of ECG-gated radionuclide ventriculography was performed during sinus rhythm and atrial pacing for 11 patients with the Wolff-Parkinson-White (WPW) syndrome. During sinus rhythm, phase analysis demonstrated abnormal early-emptying segments reflecting preexcitation in six of the 11 patients. In the remaining five patients, the precise site of abnormal early-emptying could not be detected. Atrial pacing increased the degree of pre-exicitation, and abnormal early-emptying segments became clear in all patients. Our study demonstrated the utility of atrial pacing in performing phase analysis for patients with the WPW syndrome.

Seven patients had abnormal early-emptying segments; four of them with ECG type A, in the left ventricle, and three of them with ECG type B, in the right ventricle. These results were consistent with results of the body surface and electrophysiologic mapping. In patients with posterior septal accessory pathways, phase analysis suggested probable laterality of the accessory pathway.

Key words

Phase analysis of radionuclide ventriculography　Wolff-Parkinson-White syndrome　Atrial pacing　Body surface mapping　Electrophysiologic mapping

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Recent reports indicate that phase analysis of gated radionuclide ventriculograms provides useful information as to the site of preexcitation in the Wolff-Parkinson-White (WPW) syndrome[1~4]. In this syndrome, a part of the ventricle is activated early by impulses via accessory pathways. Phase analysis can identify the site of preexcitation as an abnormally early-emptying segment. During sinus rhythm, however, the degree of preexcitation is not necessarily great, so that phase analysis sometimes fails to detect phase abnormalities. In most patients with the WPW syndrome, rapid atrial pacing can increase the degree of preexcitation[5,6]. This mechanism can improve the phase image. In this study we analyzed the effect of atrial pacing on the phase image, and compared results of phase analysis with results of the body surface mapping and electrophysiologic mapping.

Methods

Patients

Eleven patients (eight males, three females) with an electrocardiographic (ECG) evidence of preexcitation whose ages ranged from 15 to 44 years, with a mean age of 31 years were studied. According to the ECG classification of Ueda et al[7], four patients had type A (an R or Rs pattern in leads V_1 and V_2), three had type B (an rS pattern in leads V_1 and V_2), four had unclassified, and none had type C. Six patients had episodes of paroxysmal supraventricular tachycardia and four had atrial fibrillation. None had associated cardiac disease.

Radionuclide ventriculographic techniques

ECG-gated equilibrium radionuclide ventriculography was performed using an in vivo red blood cell labelling method using 25 mCi technetium-99m. A gamma camera (LEM-ZLC) with a 30° slant hole high sensitivity collimator was positioned for a modified left anterior oblique (LAO) view for optimum " separation " of the right and left ventricles. The cardiac cycle was " divided " into 28 intervals. Data were recorded for 5 min during sinus rhythm and for 8 min during atrial pacing, and then stored in 28 frames of 64×64 matrix resolution. Finally date were and analyzed using a Scintipac 1200 computer.

Phase analysis

The phase f the first Fourier harmonic of the time-activity curve in each image element (pixel) was computed. Phase information was displayed as a phase image. Each pixel of the blood pool image was color-coded according to its phase using 16 colors. Dark blue represented areas of earliest emptying, and red represented areas of latest emptying. The phase image can be interpreted to represent the onset of contraction in each pixel of the ventricles.

Electrophysiologic study

Three electrode catheters were positioned low in the right atrium at the atrioventricular junction to obtain His bundle electrograms, and at the right ventricular apex. In nine of the 11 patients, the fourth electrode catheter was advanced into the coronary sinus. Intracardiac electrograms from the low lateral right atrium, low septal right atrium (via the His bundle catheter), and left atrium (via the coronary sinus catheter) were simultaneously recorded. The location of the accessory pathway was determined by analyzing the retrograde atrial activation sequence during ventricular pacing and/or reentrant supraventricular tachycardia[5,6].

Body surface mapping

Electrocardiograms from 128 points on the anterior chest wall and back were simultaneously recorded at sampling intervals of 1 msec, and displayed as isopotential body surface maps. The location of the accessory pathway was deducted from the potential maximum and minimum sites during the delta wave[8~10].

Atrial pacing technique

Atrial pacing was performed using the electrode catheter remaining in the coronary sinus or a specially-designed atrial pacing wire in the right atrium, at pacing rates of 90–100 beats per min.

Results

Fig. 1 shows the surface ECGs of patient No. 1. During sinus rhythm, the ECG showed

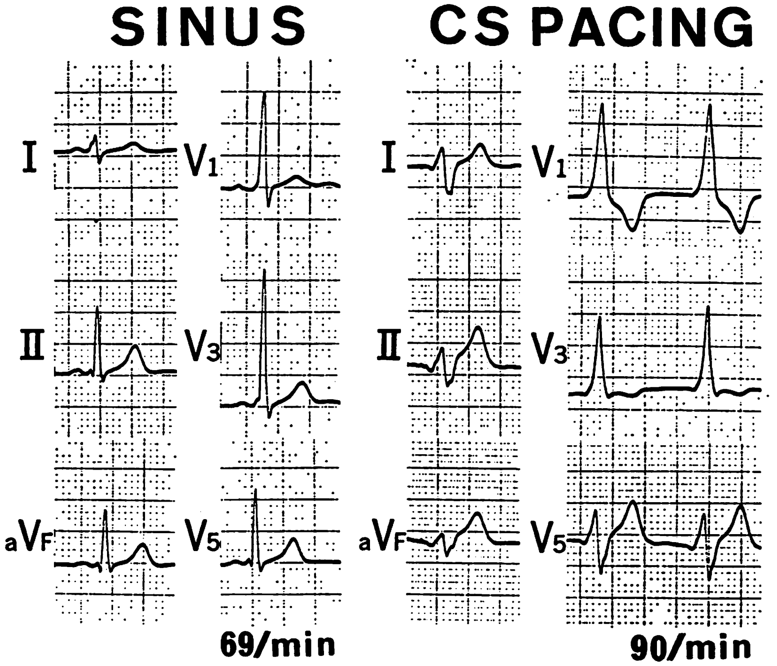

Fig. 1. Electrocardiograms of patient No. 1.
The ECG during coronary sinus pacing shows larger delta waves.

the typical pattern of type A WPW syndrome. Coronary sinus pacing increased the degree of preexcitation, manifested by larger delta waves, compared with sinus rhythm. **Fig. 2** shows the phase images obtained from the same patient. During sinus rhythm, the phase of the left ventricle (dark green) was earlier than that of the right ventricle (light green), implying that contraction of the left ventricle preceeded that of the right ventricle. However, the precise location of abnormal early-emptying reflecting the initial site of preexcitation was not identified. The phase image during coronary sinus pacing clearly demonstrated an abnormal early-emptying segment in the left ventricular base (arrow). From this area, the phase became progressively delayed as shown by the progression of dark green to lighter green toward the right ventricle. The electrophysiologic study demonstrated an accessory pathway in the left lateral free wall.

The phase images obtained from patient No. 2 with ECG type A are shown in **Fig. 3**. During sinus rhythm, the phase image showed the early phase in the right ventricular apex, but abnormal early-emptying reflecting preexcitation was not identified. Coronary sinus pacing revealed an abnormal early-emptying segment in the left lateral region. The electrophysiologic study demonstrated a left posterior accessory pathway.

The results of phase analysis, the body surface mapping and electrophysiologic mapping, and the effects of atrial pacing on phase analysis are summarized in **Table 1**. During sinus rhythm, the exact sites of abnormal early-emptying could not be determined in four patients (No. 1, 2, 3 and 9), and patient No. 10 did not have a phase abnormality. Atrial pacing revealed the abnormal early emptying segments in these five patients, although atrial pacing was not effective on phase analysis in patient No. 10 (**Fig. 4**).

In three patients with ECG type B, phase analysis during sinus rhythm clearly demonstrated abnormal early-emptying segments.

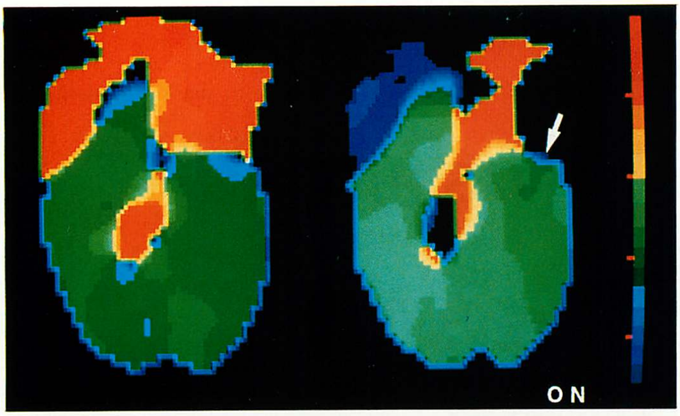

Fig. 2. Phase images of patient No. 1 during sinus rhythm (left) **and coronary sinus pacing** (right).

The phase image during coronary sinus pacing shows an abnormal early-emptying segment in the left ventricular base (arrow).

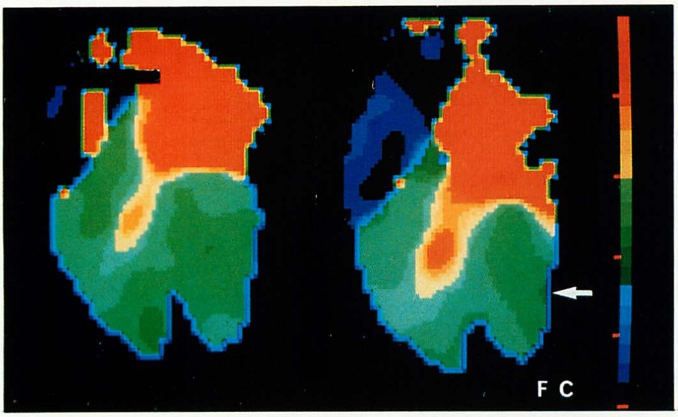

Fig. 3. Phase images of patient No. 2 during sinus rhythm (left) **and coronary sinus pacing** (right).

The phase image during coronary sinus pacing shows an abnormal early phase in the left lateral region (arrow).

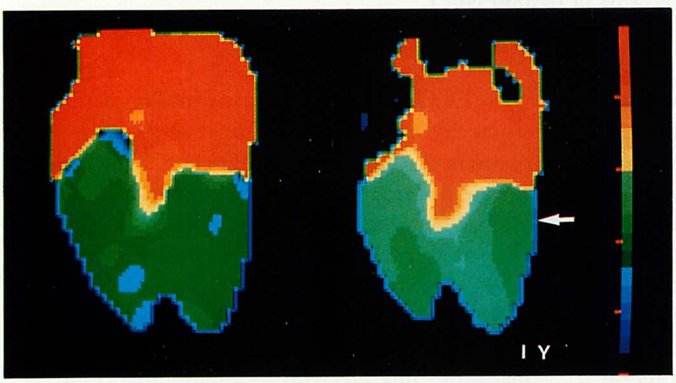

Fig. 4. Phase images of patient No. 10 during sinus rhythm (left) **and right atrial pacing** (right).

The phase image during sinus rhythm shows no phase abnormality, while the phase image during atrial pacing shows abnormal early-emptying in the left ventricle.

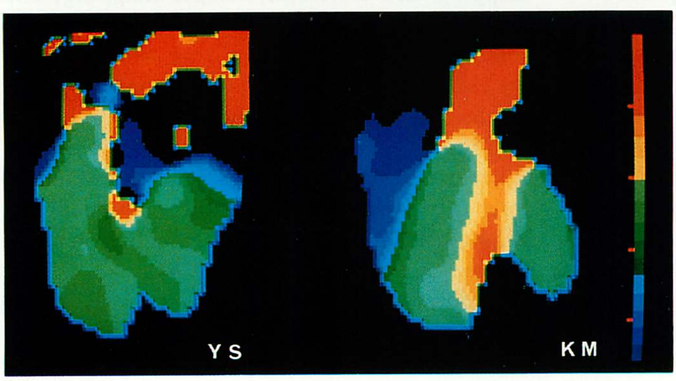

Fig. 6. Phase images from patient No. 8 (left) **and patient No. 9** (right).

The phase image from patient No. 8 shows an abnormal early-emptying segment in the left ventricular base, while that from patient No. 9 shows the similar segment in the right ventricular base.

Table 1. Results of phase analysis, the body surface mapping and electrophysio logic mapping, and effects of atrial pacing on phase analysis

Patient	ECG type	Phase analysis	BS mapping	EP mapping	Improve by atrial pacing
1	A	L	L	L	Yes
2	A	L	L	L	Yes
3	A	L	L	L	Yes
4	A	L	L	L	No
5	B	R	R	R	No
6	B	R	R	R	No
7	B	R	R	R	No
8	V_1: rs	L	S	S	No
9	V_1: rs	R	S	S	Yes
10	V_1: rs	L	L	—	Yes
11	V_1: rsR′	R	L	—	No

Abbreviations: BS = body surface; EP = electrophysiologic; L, R and S = left free wall, right free wall and septal accessory pathway; No = no alteration.

Thus, atrial pacing did not alter phase images despite an increase in the delta wave.

Four patients with ECG type A had abnormal early-emptying segments in the left ventricle; three patients with ECG type B had also the same segments in the right ventricle. These results were consistent with those of the body surface and electrophysiologic mapping.

The ECGs and body surface maps obtained from patients No. 8 and No. 9 showed no apparent differences (**Fig. 5**). The body surface maps showed the pattern of the posterior septal accessory pathway. The phase image from patient No. 8 showed an abnormal early-emptying segment in the left ventricular base, while that from patient No. 9 showed the similar segment in the right ventricular base (**Fig. 6**).

The results of phase analysis in conjunction with those of the body surface mapping suggested that patient No. 8 had a left posterior septal accessory pathway, while patient No. 9 had a right posterior septal accessory pathway. For both patients, the electrophysiologic study demonstrated the posterior septal accessory pathway, although the exact site of the accessory pathway could not be determined because of difficulty in assessing the precise location of the catheter electrode in the heart.

Discussion

Phase analysis of gated radionuclide ventriculography permits visualizing the emptying sequence of the heart. Since a mechanical contraction sequence usually follows the sequence of electrical activation, phase analysis provides useful information regarding the ventricular activation sequence[3,11~13].

Recently, identification of the site of the accessory pathway has been attempted using phase analysis[1~4]. However, a phase abnormality as a reflection of preexcitation cannot always be detected. Chan et al[1] could not detect abnormalities on phase images in two of 10 patients with the WPW syndrome. They reported that these two patients might have had septal accessory pathways and that the phase images were therefore indistinguishable from the normal. But electrophysiologic confirmation was not performed for either patient. Nakajima et al[2] reported that four of 14 patients with left ventricular accessory pathways did not show phase abnormalities. In our study, the exact sites of abnormal early-emptying could not be identified in five patients during sinus rhythm.

The QRS complex in the WPW syndrome is a fusion complex as a result of dual ventricular activations initiated by both the accessory pathway and the normal atrioventricular conduction system. A part of the ventricle is activated early by the impulse over the accessory pathway. The degree of preexcitation can vary from none to complete, depending on the relative contributions of each pathway to ventricular activation[5]. When the degree of pre-excitation is small, phase analysis may fail to detect phase abnormalities.

In most patients with the WPW syndrome, rapid atrial pacing can increase the degree of preexcitation; i.e., increase the part of the ventricle activated via the accessory pathway[6]. In our study, atrial pacing revealed abnormal

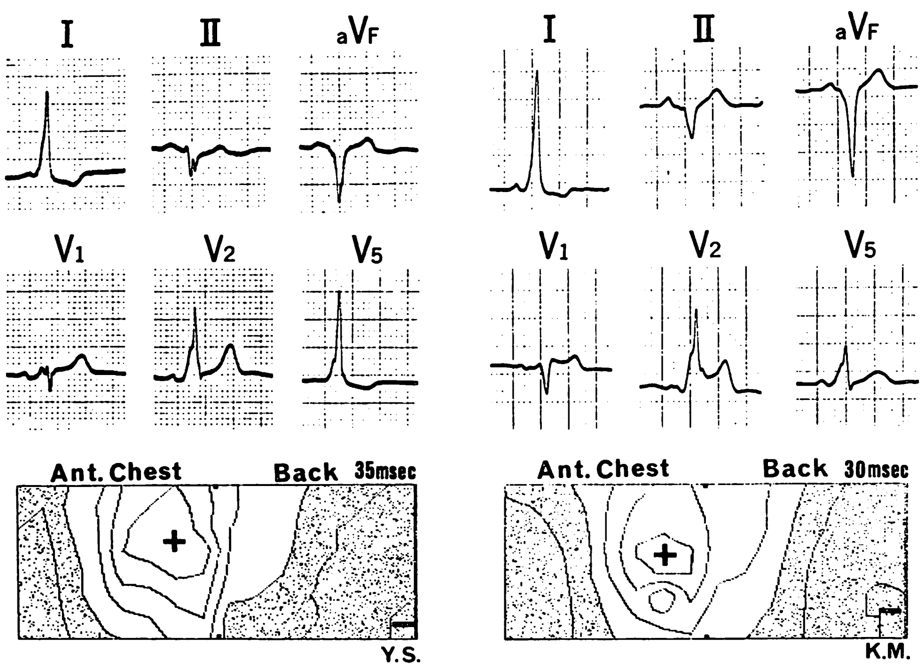

Fig. 5. Electrocardiograms and the body surface maps of patient No. 8 (left) **and patient No. 9** (right).

On the body surface maps, the areas of negative potentials are dotted. The plus and minus signs indicate the location of maximum and minimum potentials, respectively.

early-emptying segments which could not be detected during sinus rhythm. Atrial pacing is therefore useful in performing phase analysis for patients with the WPW syndrome.

Atrial pacing necessitates an invasive procedure, so it cannot be performed routinely. However, for patients undergoing electrophysiologic study, phase analysis using atrial pacing is recommended.

Chan et al[1] and Botvinick et al[2] reported that patients with septal accessory pathways did not exhibit phase abnormalities, and that a normal phase image may be characteristic of the septal accessory pathway. However, the epicardial mapping of patients with septal accessory pathways is quite different from that of normal subjects[6,14]. Therefore, it is unlikely that these patients have normal phase images. In our study, patients with septal accessory pathways (patient No. 8 and No. 9) had apparent phase abnormalities. In addition, the phase image obtained from patient No. 9 was similar to the epicardial maps of patients with right posterior septal accessory pathways[6,14,15]. This suggests that phase analysis may be useful in determining the laterality of the septal accessory pathway.

Although it is difficult to determine the exact location of the accessory pathway using phase analysis alone, this technique provides useful information and complements the electrophysiologic study.

Phase analysis による WPW 症候群の副伝導路部位の検討：心房ペーシングの意義

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WPW 症候群の 11 例を対象に，心電図同期心プールシンチグラフィーの位相解析を，洞調律時および心房ペーシング時に行った．洞調律時，早期興奮を反映する異常早期収縮部位を 11 例中 6 例で検出しえたが，残り 5 例ではその部位を明瞭には検出できなかった．心房ペーシングにより早期興奮の程度は増大し，異常早期収縮部位は全例において明らかになった．このことより，心房ペーシングは，WPW 症候群の位相解析を行うさいに有用であると考えられた．

上田らの心電図分類の A 型 4 例では左室に異常早期収縮部位を認め，B 型 3 例では右室に異常早期収縮部位を認めた．後中隔に副伝導路を有する例では，位相解析により，副伝導路が左右心室のいずれの側に近く存在するかを推定しうるものと考えられた．

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