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Phase Image Triangulation of Accessory Pathways in Patients Undergoing Catheter Ablation of Posteroseptal Pathways

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OEFF, M., ET AL.: Phase Image Triangulation of Accessory Pathways in Patients Undergoing Catheter Ablation of Posteroseptal Pathways. The outcome of posteroseptal accessory pathway ablation by direct current (DC) shocks delivered just outside the os of the coronary sinus was studied in 21 patients. Electrocardiographic and electrophysiological parameters as well as phase image patterns of equilibrium multiple-gated blood-pool scintigrams were studied to determine their usefulness in predicting the success of ablation. A second free-wall pathway was documented by electrophysiological or surgical findings in six patients, and the value of phase images in detecting this second pathway was studied as well. Ablation was successful in 57%. The cumulative mean energy of DC shocks amounted to 524 ± 170 joules and was not predictive of ablation outcome, neither was the mean ventriculoatrial (VA) conduction time. The predictive value of the 12-lead maximally preexcited electrocardiogram was poor in the 15 patients with a single posteroseptal bypass tract. A new method to triangulate the site of the earliest phase angle on the atrioventricular (AV) valve plane successfully localized the bypass pathway in 14 of those patients. No specific phase pattern predicted successful ablation except for a symmetrical, concentric peripheral phase progression found to be predictive of ablation success in the four patients who showed this pattern. Phase analysis was able to localize the second, nonposteroseptal pathway in four of six patients. This study showed that a concentric peripheral phase progression in the gated blood-pool scintigrams is predictive for ablation success in patients with posteroseptal pathways. A free-wall localization of the earliest phase angle is suggestive of a second bypass tract in this area. (*PACE*, Vol. 14, June 1991)

phase image analysis, radionuclide cardiac imaging, Wolff-Parkinson-White-syndrome, catheter ablation, tachycardia therapy

Introduction

Catheter ablation of the atrioventricular (AV) junction using direct current (DC) energy has been

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widely used for interruption of AV conduction in patients with drug-resistant supraventricular tachycardias.¹⁻⁴ This procedure has limited applicability, however, since it entails the need for permanent cardiac pacing. Ablation of an accessory pathway makes it possible to achieve a complete nonsurgical cure without need for a permanent pacemaker. However, success varies with different pathway locations. Catheter ablation of a left free-wall pathway using high energy DC shocks delivered in the coronary sinus may be complicated by coronary sinus rupture.⁵ Ablation of posteroseptal accessory pathways with the active electrodes positioned just outside the os of

the coronary sinus has been associated with good long-term success and a low morbidity rate.⁶

The clinical success of posteroseptal accessory pathway catheter ablation, however, is also influenced by the presence of additional bypass tracts, which are found in a significant number of patients.⁷⁻⁹ Their identification requires special attention in the assessment of electrocardiographic and electrophysiological results. Still, such scrutiny is not always helpful in the identification of dual pathways, since these patients may be activated only through the septal pathway.⁸

Conventional invasive electrophysiological techniques are helpful in localizing the atrial insertion site of accessory AV bypass tracts.¹⁰ A non-invasive tool that has been applied for localization of ventricular preexcitation is phase image analysis of multiple-gated equilibrium blood-pool scintigrams of the heart.¹¹⁻¹³ However, the predictive characteristics of preoperative study parameters for successful ablation are still controversial.

The purpose of this report is to identify those patients in whom catheter ablation procedures directed at posteroseptal accessory pathways is most likely to be successful. The outcome of catheter ablation was correlated to preablation electrophysiological parameters, maximally preexcited 12-lead surface electrocardiograms and the characteristics of phase image analysis during sinus rhythm and with atrial pacing. In addition, the value of the noninvasive studies in detecting multiple accessory bypass tracts in this setting is investigated.

Methods

Patients' Characteristics

This study included 21 consecutive patients with the Wolff-Parkinson-White syndrome, 10 men and 11 women, who had electrocardiographic and electrophysiological findings characteristic of antegrade conduction over a posteroseptal bypass tract and recurrent symptomatic reciprocating orthodromic tachycardias. Only patients with the earliest atrial excitation at the os of the coronary sinus were included in this study. All patients were studied except those with con-

cealed pathways or those who did not undergo the phase image study.

Routine echocardiographic studies excluded the presence of Ebstein's anomaly in these patients. The mean age was 34.1 ± 11.1 years (mean \pm SD) with a range of 18 to 62 years. Antiarrhythmic drugs had either been ineffective or had involved intolerable side effects in all cases.

Baseline Electrophysiological Study

After having given informed consent, each patient underwent an electrophysiological study prior to catheter ablation. Quadripolar electrode catheters were introduced into the femoral and subclavian veins and positioned in the high right atrium, right ventricle, coronary sinus, and across the tricuspid valve to record His-bundle activity. The accessory pathway conduction properties and refractory periods were determined by rapid atrial and ventricular pacing and programmed atrial and ventricular stimulation.

Orthodromic AV reciprocating tachycardia was induced in all patients with the exception of two, who had previously presented with atrial fibrillation only. The localization of accessory pathways was confirmed by determination of the ventriculoatrial (VA) conduction time along the coronary sinus, and a modified Brockenbrough electrode catheter (USCI, Billerica, MA, USA) was used for mapping the tricuspid annulus. The atrial electrograms were recorded during orthodromic reciprocating tachycardia or ventricular pacing.

A posteroseptal accessory pathway was diagnosed if the earliest atrial activation was recorded at the os of the coronary sinus. Fifteen patients were found to have single posteroseptal pathways, while six showed evidence of dual accessory pathways with the second pathway in the right or left free wall. In five patients, evidence of the second, nonposteroseptal pathway was found at baseline electrophysiological study. In one patient with a right anterior pathway, the presence of an additional pathway was diagnosed electrophysiologically only after successful ablation of the posteroseptal pathway. Five of the six patients with dual pathways subsequently underwent surgery for interruption of the bypass tracts. In each instance, the free-wall pathway was correctly localized intraoperatively.

Standard Electrocardiogram

Electrocardiographic classification of the Wolff-Parkinson-White syndrome was done by analysis of the mean vector of the delta wave in the 12-lead standard electrocardiogram according to Gallagher et al.¹⁰

A typical 12-lead electrocardiogram for posteroseptal preexcitation had a negative delta wave in standard lead III and lead aVF and generally also in standard lead II with a small delta wave in lead V₁ but a clearly positive delta wave in lead V₂. An electrocardiogram was considered atypical if tall R waves were present in standard lead II and/or if the typical changes in the delta waves in V₁ and V₂ were not present.

Phase Image Analysis

The patients underwent phase image analysis to localize ventricular preexcitation immediately after the electrophysiological study. The scintigrams were recorded during sinus rhythm and with atrial pacing. Atrial pacing was performed to maximize preexcitation; use was made of the electrode catheter left in the coronary sinus after the baseline electrophysiological study. The results of the electrophysiological study and phase image analysis were evaluated by different observers, each blinded to the results of the other study.

Equilibrium multiple-gated blood-pool scintigrams were acquired with a standard 37-photo-tube Searle Pho-gamma 5 scintillation camera or portable Ohio Nuclear Series 120 or Siemens LEM cameras (Siemens-Elema, Solna, Sweden) using a linear all-purpose 20° slant-hole collimator and processed on a PDP 11/40 mini-computer (Digital Equipment Corp., Marlboro, MA, USA). All patients were imaged in anterior, "best septal" left anterior oblique and 70° left anterior oblique (LAO) projections as described earlier.¹¹ The different individual angles of the "best septal" LAO projection, which ranged from 35° to 55°, were considered.

Phase image analysis was performed using the fundamental Fourier harmonic applied to the first 25 frames of the blood-pool study.¹⁴ The phase image was displayed on a monitor screen and analyzed stepwise; phase angle or regional phase delay was coded from the static phase images in 256 gray shades.

A new method was developed to triangulate the site of earliest phase angle to the AV valve plane. The site of earliest phase angle in each phase image was taken to represent the site of earliest electrical activation and was projected onto the AV valve plane. The intersections of these projected lines localized the area of preexcitation. In order to maintain impartiality, this method was applied blindly to the phase images of 42 patients with ventricular preexcitation, including the 21 subjects of the present study.

As previously reported,¹¹ a lateral right or left free-wall focus was localized when the earliest phase angle was projected in the lateral wall in the "best septal" LAO and 70° LAO projection with delayed phase angle progression in the contralateral ventricle.

A posteroseptal focus was localized if the earliest phase angle was projected to (or near) the septum with symmetrical phase progression to both ventricles in the "best septal" LAO and from posterior (or inferior) to anterior regions in the anterior and 70° LAO projections.

Additionally, the following phase image patterns were established in patients with posteroseptal pathways:

1. Mid-septal site of earliest phase angle. This resembles the normal pattern in the absence of preexcitation;¹⁴

- 2a. Posteroseptal site of earliest phase angle with phase progression from posterior or inferior to anterior regions;

- 2b. Posteroseptal as in 2a but with additional early phase angle at the left or right ventricular free wall, probably depending on ventricular angulation as well as activation;

- 2c. Posterior septal as in 2a but with simultaneous symmetrical concentric peripheral activation of lateral aspects of both right and left ventricle progressing centrally;

3. Right ventricular free-wall site of earliest phase angle;

4. Left ventricular free-wall site of earliest phase angle.

Free-wall pathways differed from septal pathways in that there was sequential spread of activation from the ipsilateral ventricle to the septum with final activation of the contralateral ventricle. In contrast, septal pathways showed early septal

activation followed by almost synchronous activation of both ventricles.

Catheter Ablation Protocol

Each patient gave informed consent for ablation according to a protocol approved by the Committee on Human Research at the University of California, San Francisco. Patients with dual pathways chose to undergo an attempt at catheter ablation of the posteroseptal accessory pathway in the hope of improving symptoms or facilitating subsequent surgical ablation of the remaining pathway; the ablation of the free-wall pathway was not attempted.

As described earlier,³ a quadripolar 6 or 7 French central lumen catheter (USCI) was inserted into a subclavian vein and positioned in the coronary sinus under fluoroscopic guidance. After visualization of the os of the coronary sinus by injection of contrast material, either the same catheter or a newly inserted quadripolar ablation catheter with an interelectrode distance of 1 cm (USCI) was repositioned in such a way that the proximal pair of electrodes were positioned just outside the os of the coronary sinus.

Both proximal electrodes were connected to the cathodal output of the defibrillator (Physio-Control, Redmond, WA, USA), while the anodal sink of the defibrillator was connected to a patch electrode 16 cm in diameter (R2 Corp., Skokie, IL, USA) placed over the mid-thoracic spine. The patients were anesthetized with sodium thiopental, and two or three 150- to 400-joule discharges synchronized to the QRS were delivered within 10 minutes.

The short-term effect of the shock on the accessory pathway was determined by atrial and ventricular stimulation 5 to 10 minutes thereafter. Reappearance of the preexcitation was determined by ambulatory monitoring and 12-lead electrocardiograms. The patients were followed up for a mean of 24.5 ± 17.6 months (range 6–66 months). Failures were defined as recurrence of accessory pathway conduction or spontaneous recurrence of tachycardia. In addition, all patients were submitted to a repeat electrophysiological study approximately 3 months after ablation.

Five of six patients with dual accessory pathways underwent surgical ablation of the nonseptal

accessory pathway. The posteroseptal localization was corroborated intraoperatively in those with failed ablation and the conduction properties of the posteroseptal pathway were determined. The free-wall pathways were located at the right lateral free wall in four cases, at the right anterior wall in one case and at the left free wall in one other case.

Statistical Methods

The tabular data are expressed as means \pm standard deviation. The significance of differences in delta-wave progression, VA time and ablation energy were determined using Student's "t"-test for unpaired values. The significance of differences in phase image pattern groups with regard to the ablation outcome was determined using the Chi²-test with Yates' correction. A P value <0.05 was considered significant.

Results

Noninvasive Localization of Ventricular Preexcitation

Electrocardiographic patterns and the results of the phase image analysis were used for noninvasive localization of the accessory pathway. Tables I and II present these results together with the electrophysiological data and the energy setting for the catheter ablation procedure as well as its outcome.

Electrocardiogram

Sinus Rhythm. Fifteen patients showed a typical pattern for a posteroseptal pathway in the standard 12-lead electrocardiogram with no R waves in leads III and aVF and a delta wave progression of 1.03 ± 0.8 mV between V_1 and V_2 with an initial delta wave amplitude of 0.12 ± 0.1 mV in V_1 (Fig. 1). Four of the 15 patients had dual accessory pathways, and the electrocardiogram showed no evidence for ventricular activation through the second bypass tract.

Four patients with only a single posteroseptal accessory pathway had an atypical pattern with absence of delta wave progression from V_1 to V_2 in the chest leads (# 9 and 20) or preexcitation associated with a positive delta wave in lead II (# 13 and 21).

Table I.

Patient	Age/Sex	Dual AP's	ECG		Phase-Image		VA Time (msec)	Cumulative Ablation Energy (joules)	Ablation Outcome
			Sinus Rhythm	Atrial Pacing	Sinus Rhythm	Atrial Pacing			
1	42/f		T	T	2b	2c	105	400	success
2	42/m		T	T	2a	—	125	300	failure
3	22/m		T	T	1	2b	115	700	success
4	62/f		T	T	2b	2c	90	500	success
5	22/m	+ L-lat	A	A	4	4	85	400	failure
6	39/f	+ R-lat	T	T	3	3	93	200	failure
7	33/m		T	T	1	2c	150	800	success
8	27/f		T	T	2a	2c	60	400	success
9	26/m		A	T	1	2b	105	500	failure
10	32/m		T	T	1	2b	80	500	failure
11	50/f	+ R-lat	A	A	3	3	130	800	success
12	37/f		T	T	3	3	85	400	failure
13	22/f		A	T	1	2b	80	500	success
14	36/f		T	T	2a	2b	110	400	success
15	18/m		T	T	1	2b	StA 165	700	failure
16	29/f	+ R-ant	T	T	2a	2a	105	600	success
17	37/m		T	T	1	2b	StA 190	400	success
18	39/m	+ R-lat	T	T	2a	2a	87	500	success
19	31/m	+ R-lat	T	T	3	3	95	800	failure
20	49/f		A	T	2b	2b	125	700	failure
21	21/f		A	T	1	2b	80	500	success

Specific patient characteristics and findings in surface electrocardiogram, phase image analysis, and electrophysiological study, ablation energy and long-term outcome of ablation are presented here.

Explanation of phase image patterns: see Method section, AP = accessory pathway; ECG = electrocardiogram; VA time = ventriculoatrial conduction time; T = typical ECG pattern; A = atypical ECG pattern; L-lat = left-lateral, R-lat = right-lateral; R-ant = right-anterior; StA = Stimulus-A interval.

Table II.

	Success	Failure
	n = 12 (57%)	n = 9 (43%)
Standard-ECG, n = 15		
Typical configuration	9	6
Delta-wave progression (V ₁ to V ₂ , mV)	0.9 ± 0.6	1.1 ± 0.6 (NS)
Ventriculoatrial conduction time, n = 19	101 ± 25 msec (NS)	99 ± 18 msec
Phase image analysis, n = 15		
Concentric peripheral, posteroseptal (2c)	4	0
Posterior to anterior, posteroseptal (2a and b)	5	5
Lateral (3)	0	1

This summarizes the outcome of catheter ablation of the posteroseptal pathway in relation to the standard electrocardiogram configuration with maximum preexcitation, ventriculoatrial conduction time and phase image analysis; patients with dual pathways are omitted in the electrocardiographic and phase image evaluation. The type of phase image pattern is indicated in parentheses.

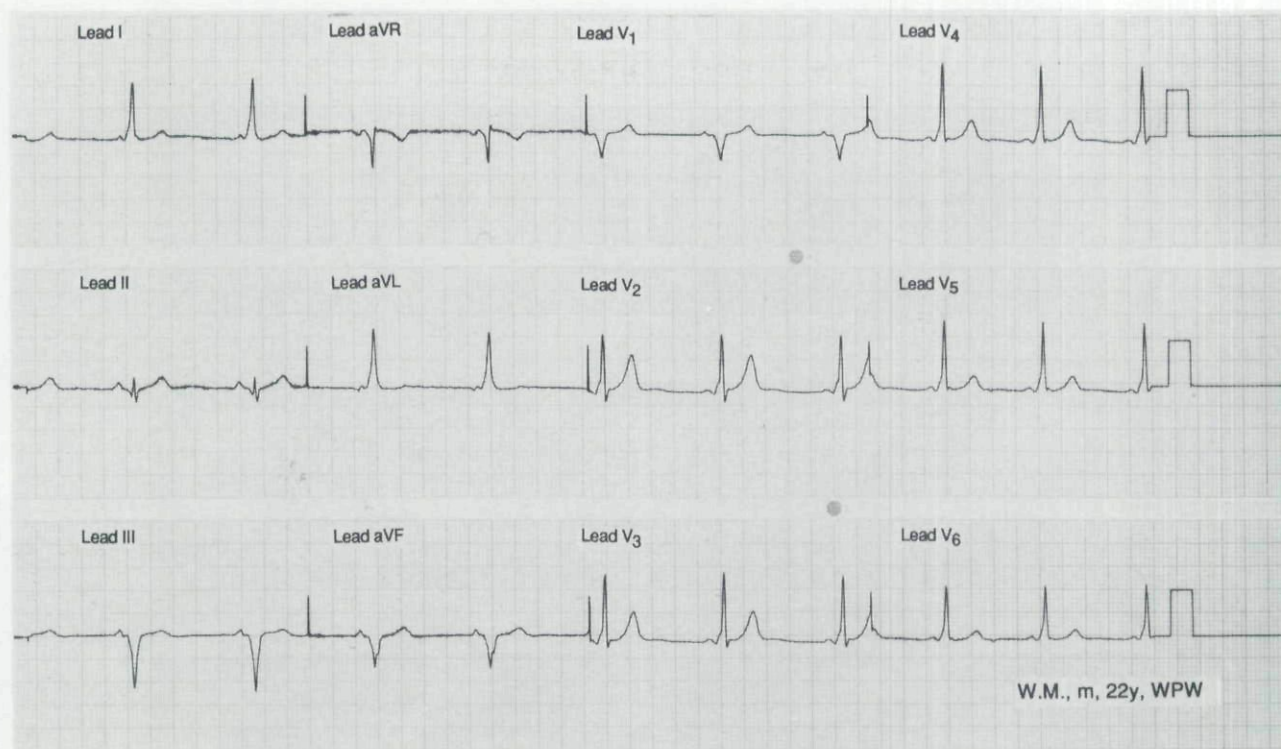


Figure 1. Typical electrocardiogram. This figure shows the typical electrocardiographic pattern of a patient with a posteroseptal accessory pathway with negative delta wave polarity in leads II, III, and aVF, a small delta wave in lead V₁ and a markedly positive delta wave in lead V₂.

One patient with a posteroseptal and left free-wall pathway (# 5) had an electrocardiogram configuration compatible with a left free-wall pathway; and, in one patient (# 11) with an additional right-sided pathway, the electrocardiogram was consistent with a right free-wall pathway.

Atrial Pacing. During atrial pacing, the atypical electrocardiogram configuration present during sinus rhythm in four patients with a single posteroseptal accessory pathway changed to a typical electrocardiogram pattern with a significant decrease of the positive delta wave in lead II, a small delta wave in V₁ followed by a large amplitude of the delta wave in V₂.

The electrocardiogram pattern did not change significantly in the patients with dual accessory pathways.

Phase Image Analysis

In 16 of 21 patients, triangulation of the earliest phase angle localized the site of earliest ven-

tricular excitation to the posterior septal region (Figs. 2 and 3). Two of these showed a right paraseptal localization in the "best septal" LAO projection. This may have been related to projection, since the localization was posteroseptal in the two other projections. Eight of these displayed the normal mid-septal site of earliest phase angle in sinus rhythm, but there was an obvious shift to the posteroseptal focus during atrial pacing (Fig. 2). The phase image demonstrated enhanced localization of the focus with atrial pacing in all cases (patterns 2a and 2b).

In four of these patients, during atrial pacing, a symmetrical concentric peripheral phase progression of both right and left ventricle in the "best septal" LAO projection was found with early posterior activation in the anterior projection (pattern 2c, Fig. 4).

The earliest phase angle was seen in the right lateral free wall in four patients (Figs. 5 and 6) and in the left lateral free wall in one patient.

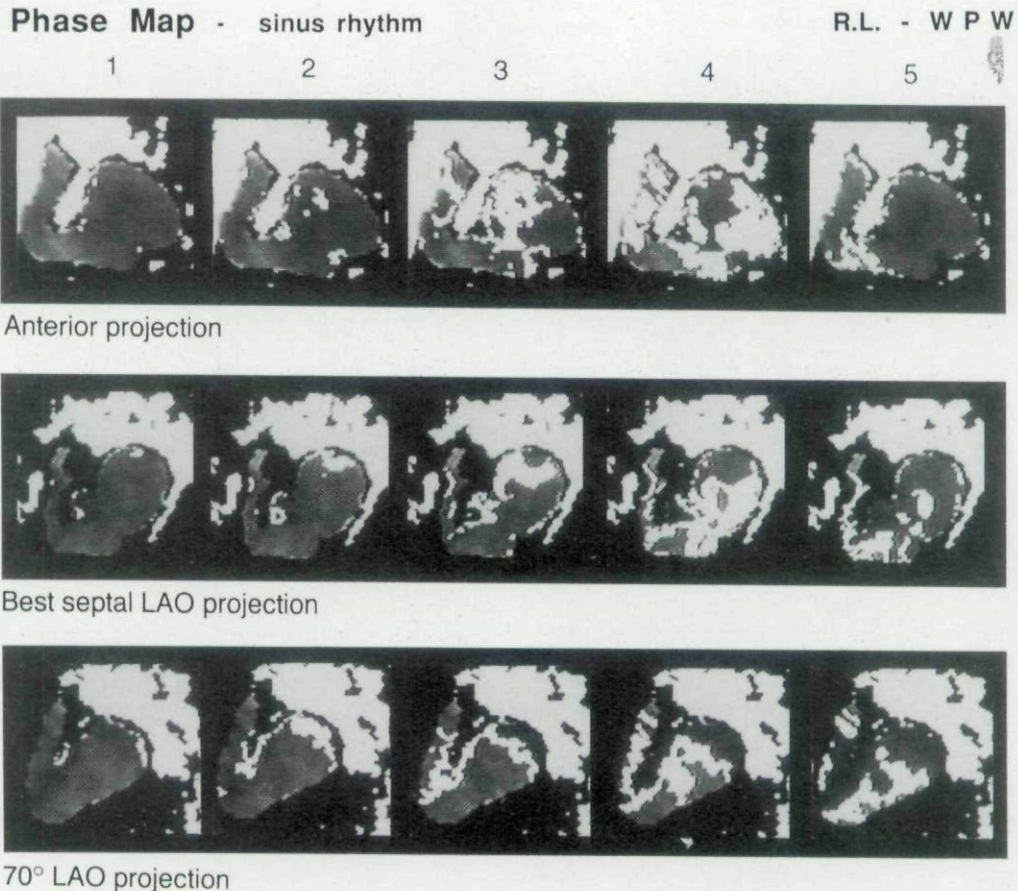


Figure 2. Phase image analysis. A. Phase image analysis of the anterior, "best septal" left anterior oblique (LAO) and 70° left anterior oblique scintigram projections in a patient with a posteroseptal accessory pathway. Earliest phase angle (black) is seen in the posteroseptal area. In each image (1–5), sequential phase angle progression is shown with a serial highlight in white of the region with increasing phase angle. This pattern would be categorized as 2b (posteroseptal site of earliest phase angle with phase progression from posterior or inferior to anterior regions and additional early phase angle at the right ventricular free wall).

Of the six patients with dual pathways, three had the earliest phase angle projected to the right free wall and one to the left free wall. This was the correct localization of the second, nonposteroseptal pathway according to the electrophysiological study. In two patients with an additional right-sided pathway, earliest phase angle was present only in the posteroseptal area.

In one patient (# 12) with only a single pathway at the posterior septum according to the electrophysiological study, the phase image revealed a right lateral localization of ventricular activation. In only this one case was there a discrepancy

between the phase image and the electrophysiological localization.

In two patients, the additional right-sided pathway was noninvasively recognized only by phase image analysis, since the electrocardiogram pattern was typical for posteroseptal localization only, even during atrial pacing and induced atrial fibrillation.

Catheter Ablation of the Posteroseptal Pathway

The single DC ablation shock was 150 to 400 joules in strength, the cumulative energy being

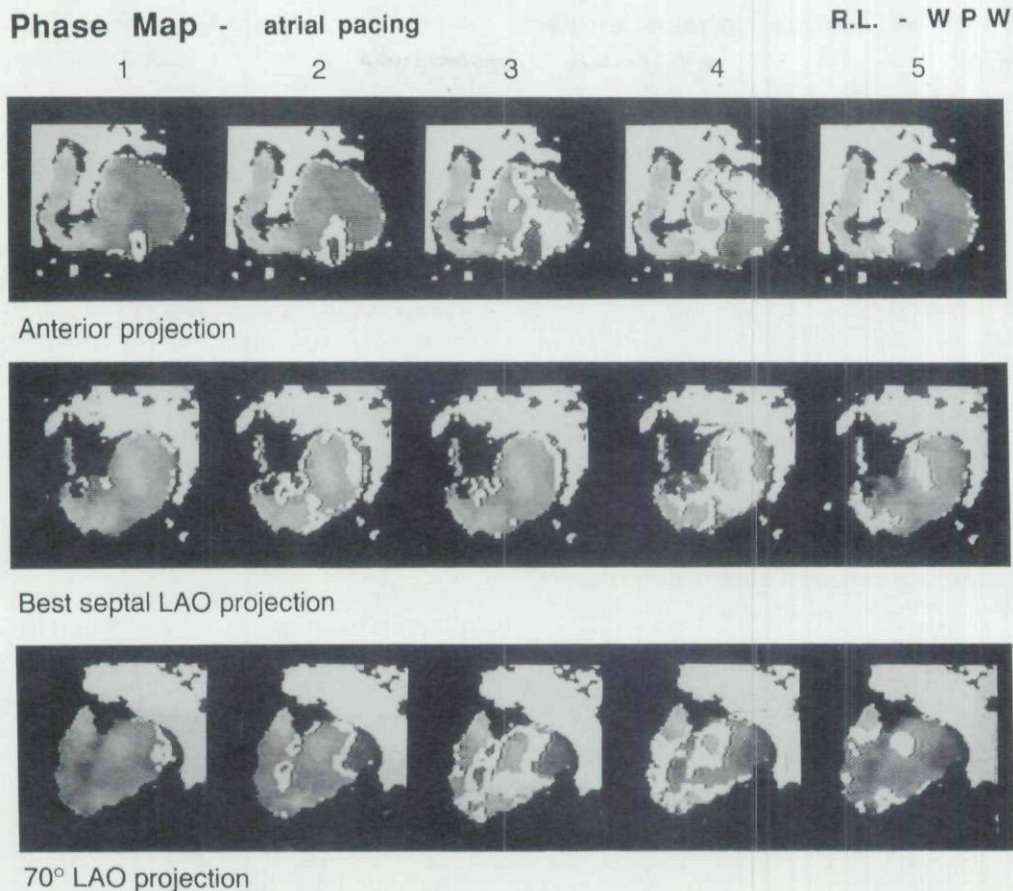


Figure 2B. A more pronounced preexcitation of the posteroseptal area in the same patient during atrial stimulation is presented in the same way as in Figure 2A.

200 to 800 joules (mean 524 ± 170 J). During the follow-up period, 12 patients remained event-free (57%) or showed no evidence of antegrade or retrograde conduction through the posteroseptal accessory pathway during the electrophysiological study. Three of these patients had a free-wall accessory pathway, which was treated by surgery in two cases. Intraoperative electrophysiological testing revealed no conduction through the posteroseptal pathway.

In nine patients, catheter ablation of the posteroseptal pathway failed; delta waves reappeared in the electrocardiogram, and there was recurrent AV reciprocating tachycardia. Three of these patients had dual pathways and were submitted to surgery. Conduction through the posteroseptal pathway was present during intraoperative testing.

Results Predictive for Outcome of Posteroseptal Pathway Ablation

VA Conduction Time and Ablation Energy (Table II)

The mean VA activation time during orthodromic AV reentrant tachycardia was 100.3 ± 21.9 ms (range 60 to 150 ms). The VA conduction time was 101 ± 25 ms for patients with successful ablation and 99 ± 18 ms in those with failed ablation (NS).

The applied cumulative energy was not predictive of ablation success: it was 541 ± 150 joules in successful cases and 500 ± 200 joules in cases where ablation failed (NS).

To exclude the influence that the second, free-wall pathway exerts on the electrocardiogram and phase image studies, data from 15 patients with a

**Localization of earliest phase angle
R.L. - WPW**

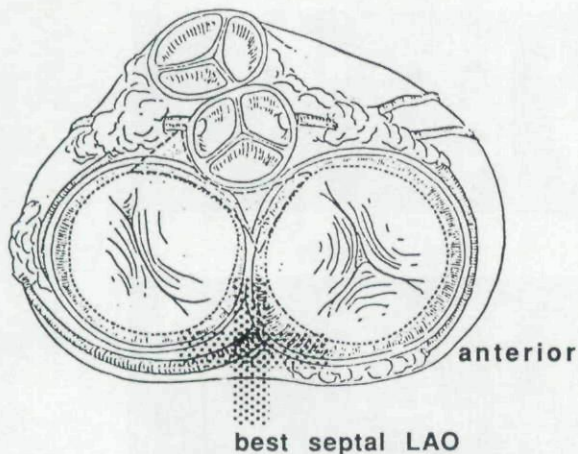


Figure 3. Phase image triangulation. The site of the earliest phase angle obtained in the planes described in Figure 2A is projected onto the atrioventricular valve plane. LAO = left anterior oblique.

single pathway are listed separately in Table II. Nine of these had successful ablation, and six did not.

Electrocardiogram (Table II)

The electrocardiogram during sinus rhythm had a typical configuration in seven of nine cases (78%) with successful ablation and in four of six (67%) with failures (NS). With maximum preexcitation during atrial pacing, the delta wave progression from V₁ to V₂ was 0.9 ± 0.6 mV in patients with successful ablation and 1.1 ± 0.6 mV in those with failed ablation (NS).

Phase Image Analysis (Single Pathway) (Table II)

The symmetrical concentric peripheral phase progression (pattern 2c) was found in four patients with successful ablation of the posteroseptal pathway (Fig. 4) but never in those with failed ablation ($\chi^2 = 4.58, P = 0.1$). Earliest septal phase angle with phase progression from the posteroseptal area and the left or right posterior and lateral walls (pattern 2a or 2b) was found in five with successful and five with unsuccessful ablation, while ablation failed in one patient whose earliest phase angle was located at the right free wall but who had a posteroseptal accessory pathway in the electrophysiological study (# 12).

Table III.

	Single AP, Posteroseptal	Dual AP, Posteroseptal and Free Wall
Standard ECG		
Typical configuration	15	4
Atypical configuration	0	2
Phase image analysis (site of earliest phase angle)		
Posteroseptal	14	2
Right lateral	1	3
Left lateral	0	1

Electrocardiogram and phase image identification of dual accessory pathways. Prediction of a second bypass tract in patients with single posteroseptal and free wall pathways by standard electrocardiogram with maximum preexcitation and phase image analysis is assessed here. AP = accessory pathway.

Phase Image Analysis (Dual Pathways) (Table III)

In four of the six patients with dual pathways, the preexcitation site of earliest phase angle was localized at either the right (# 6, 11, and 19) or the left free wall (# 5). All had a second pathway in this area.

In two of the four patients with the correctly identified second, free-wall pathway (# 6 and 19), the electrocardiogram yielded the typical pattern for a posteroseptal pathway even during atrial pacing, and only the phase image suggested an additional free-wall pathway. In the remaining two patients (# 5 and 11), the 12-lead electrocardiogram also yielded evidence of a free-wall pathway. In this group with dual pathways, there were three successful and three failed ablations.

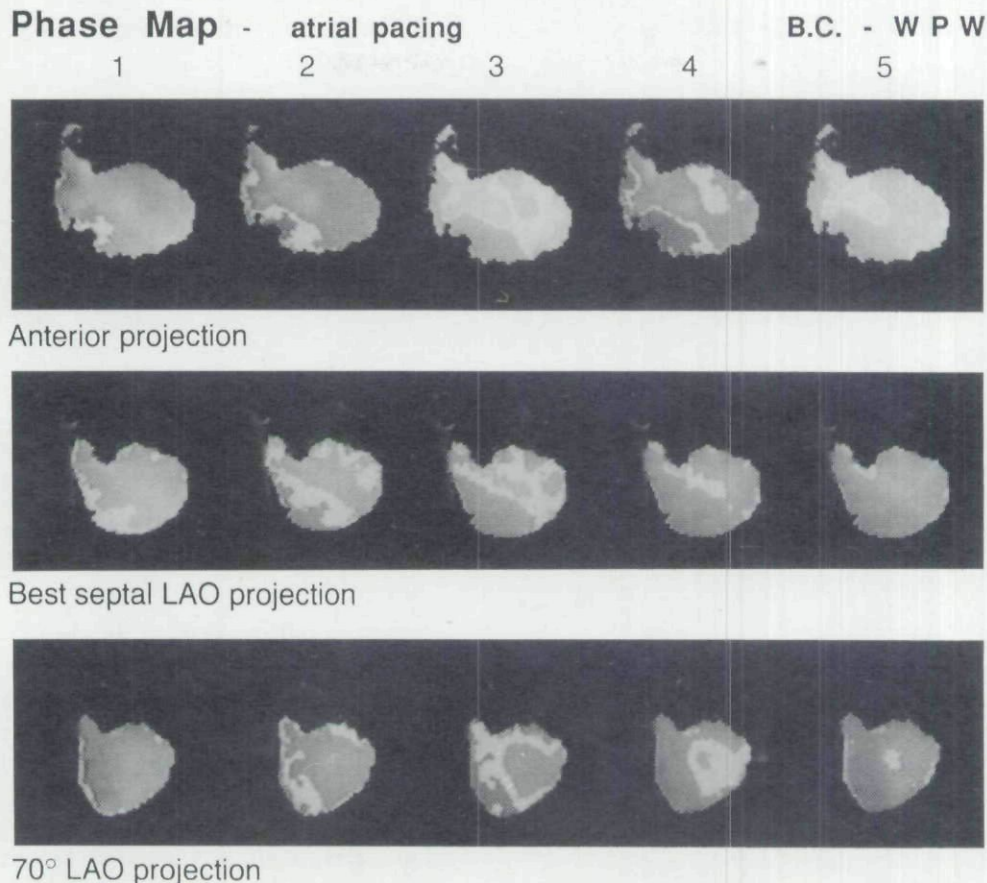


Figure 4. Phase image analysis: Concentric peripheral phase progression. This figure illustrates the symmetrical concentric peripheral activation of the right and left ventricles in the "best septal" left anterior oblique (LAO) projection of the phase image. This pattern was found in four patients with successful ablation of the posteroseptal pathway but in none of those with failure of catheter ablation. The cause of this symmetrical pattern is not specifically known.

Discussion

We identified a posteroseptal accessory pathway by the presence of earliest retrograde atrial activation at the os of the coronary sinus. In 57% of our patients, transcatheter DC shocks delivered at this site made it possible to completely eliminate accessory pathway conduction. Success rates of 63 to 68% were reported in other studies using the same approach.^{6,15,16} Our success rates were somewhat lower than those reported by Morady et al.,⁶ since we excluded patients with concealed conduction through the accessory pathway. These patients were reported to have a 100% ablation success.⁶

Warin et al.¹⁷ sought to ablate the site of ac-

cessory pathway potential recording and had clinical success in all 32 patients with posteroseptal pathway localization; despite that in five preexcitation resumed, no tachycardia could be induced in the control electrophysiological study.

Recently, successful ablation of septal and free-wall accessory pathways was achieved using radiofrequency energy.¹⁸⁻²¹ The desiccation of the tissue through resistive heating allows controlled energy delivery and has not been associated with percussive shock waves. Thus, energy delivery is allowed even within the coronary sinus without serious complications.²²

Careful mapping of the region of the coronary sinus ostium with recording of the posteroseptal accessory pathway activation revealed distinct lo-

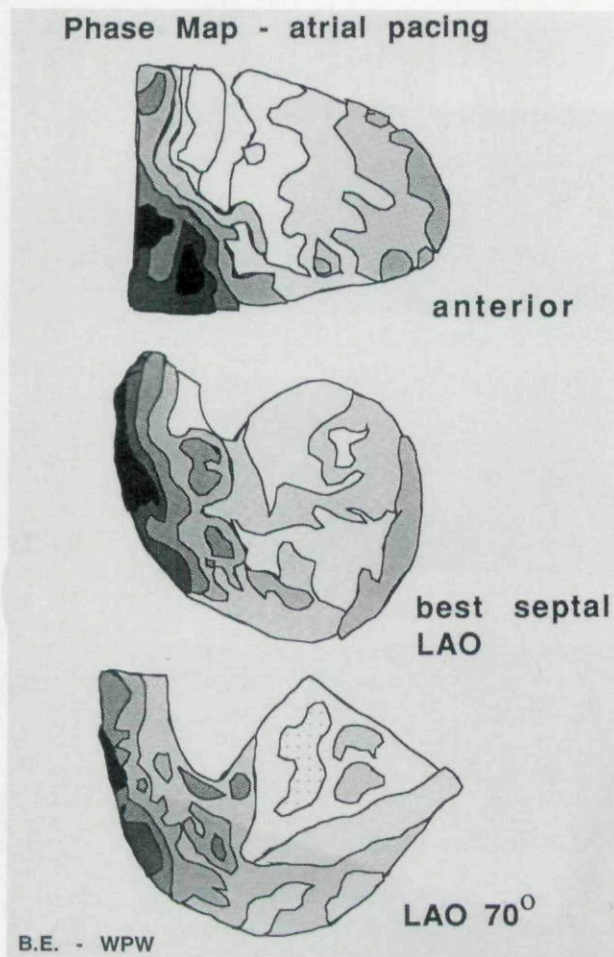


Figure 5. Phase image analysis: Dual pathways. The diagram illustrates the phase image analysis of the anterior, "best septal" left anterior oblique and 70° left anterior oblique LAO scintigram projection in a patient with dual bypass tracts (posteroseptal and right lateral). Here, as in true phase images, the phase angle is shown in black with progressive lightening paralleling phase angle progression. Earliest phase angle is noted in the right lateral free wall. Electrocardiogram showed typical pattern for posteroseptal pathway and gave no evidence of the free-wall pathway.

cations inside the coronary sinus (left posteroseptal) as well as along the tricuspid annulus anterior to the coronary sinus ostium (mid-septal) or across or immediately posterior of the ostium (right posteroseptal).²³ Ablation at these sites using radiofrequency energy provides a high success rate, especially if large tip electrodes were used.^{20,21}

These variable positions and anatomy of the

Localization of earliest phase angle
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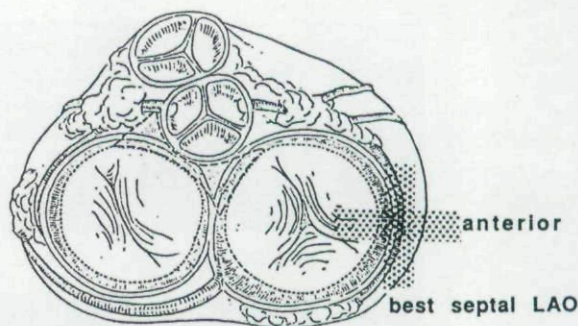


Figure 6. Phase image triangulation. The site of earliest phase angles corresponds to the right-sided preexcitation pathway in the patient with dual accessory pathways (posteroseptal and right-lateral localization), illustrated in Figure 5. LAO = left anterior oblique.

accessory pathway may determine the ablation outcome. Intraoperative recordings of antegrade ventricular excitation and retrograde atrial activation²⁴ and recording of activation potentials from accessory pathways²³ revealed in many instances an oblique course of the accessory pathway or fanlike dispersion at the atrial or ventricular insertion sites. A variety of positions is found intraoperatively in the "complex posterior septal space."²⁵ The atrial insertion site for these patients with posteroseptal accessory pathways is on or close to the os of the coronary sinus. The pathways' course through the posterior septal space insert into either the left or right ventricle, but "atypical" locations intraseptally near the AV node on the left atrial endocardial surface are possible.²⁶ The exact pathway position may be missed, since recordings of accessory pathway potentials^{23,27} for its localization cannot always be obtained.

The objective of the present study was to determine whether success of the ablation procedure could be related to specific ventricular contraction patterns or to electrophysiological parameters.

Predictors of the Ablation Outcome

VA Activation Time and Ablation Energy

The VA activation time during orthodromic tachycardia reflects retrograde conduction through the accessory pathway. It was suggested

that a short VA interval during orthodromic tachycardia may indicate catheter proximity to the accessory pathway and has been found by some to be predictive of successful accessory pathway ablation.¹⁵ We, however, like others,¹⁶ did not find a correlation between VA conduction time and ablation outcome. The reason for this discrepancy is not known. It should be pointed out that the value of interpatient comparison of the VA interval is uncertain because the QRS duration may vary widely during tachycardia.

In the present study, the amount of DC shock delivery through the electrodes just outside the os of the coronary sinus was not shown to be predictive for the ablation outcome. This was also suggested by previous studies.^{15,16}

Electrocardiogram

Body surface maps allow successful noninvasive localizations of accessory pathways by using either the time-based isopotential map²⁸ or the criteria of the initial minimum potential.^{29,30} Localizations have also been achieved by analyzing the delta wave vector in the standard electrocardiogram.^{10,31} In the present study, 11 of 15 patients with a single accessory pathway had, during sinus rhythm, an electrocardiographic pattern that was compatible with a posteroseptal localization. Four additional patients evidenced different degrees of fusion during sinus rhythm, which resulted in an atypical electrocardiographic configuration. Atrial pacing in the coronary sinus produced a typical pattern in all patients. But none of the reported electrocardiographic criteria during maximum preexcitation were predictive of ablation outcome.

We suggest that, while the maximally preexcited QRS is highly predictive of posterior septal or paraseptal pathways, it is not sufficiently sensitive to separate those posteroseptal pathways (as we have defined them) from adjacent paraseptal locations. Previous reports have documented the value of changes in the VA interval corresponding to the development of bundle branch block patterns in the differentiation of septal from free-wall pathways.³² While only small changes in the VA interval were always documented in those who developed a left bundle branch block pattern in our study, this finding is of limited value, since

our experience indicates that posterior paraseptal pathways will also show such changes.

Phase Image Analysis

According to a previous study, this technique proved highly accurate for the localization of any region of ventricular preexcitation.¹¹ Inherent errors exist, however, in the production of the phase image. They were investigated previously and considered in this analysis. These problems concern the curve fit to the increasingly delayed phase angle, the only relative expression of the sequential contraction pattern and errors in the counts data, which are subject to cardiac wall motion and overlapping structures.¹¹

In this study, we have established the phase image pattern in patients conducting via a posteroseptal accessory pathway. Noninvasive determination of the site of ventricular preexcitation using phase image analysis of the gated blood-pool scintigram correlated well with the electrophysiological localization. Fourteen of the 15 patients with a single pathway in the posteroseptal area had the site of earliest phase angle in the middle or posterior septum. In all of the eight patients with the same pattern previously found in patients with normal conduction,¹⁴ atrial pacing in the coronary sinus provided for maximum ventricular preexcitation and produced a posterior shift of the ventricular activation site, thus permitting correct localization of the posteroseptal site, as described earlier.³³

To avoid reliance on single-plane localization, as in some previous cases,¹² and to correlate the image with the electrophysiological data, we applied a new method of triangulation using three planes. The earliest phase angle in each phase image was projected onto the AV valve plane.

All four patients with symmetrical concentric peripheral phase angle progression of both ventricles in the "best septal" LAO projection with earliest phase angle posteriorly in the anterior projection had successful ablation of the posteroseptal pathway. Only five of ten patients with earliest phase angle in the posterior or inferior septum and phase progression to anterior regions were successfully ablated. Although these differences were not statistically significant, they suggest that this type of activation may reflect a pathway that is

predominantly intraseptal. Since none of the failed ablations showed the symmetrical concentric pattern, this finding appears to be highly specific but very insensitive for prediction of successful ablation. In previous studies,³⁴ phase imaging was found to differentiate between left-sided, right-sided, and septal sites of ventricular activation by pacing in the same patient, suggesting adequate spatial resolution for our purposes.

In one patient, there was a gross discrepancy between localization by scintigraphy (right free wall) and endocardial mapping. Since this occurred in a patient with failed ablation who refused surgery, it is unclear which of the two methods was incorrect.

Phase analysis was helpful in corroborating the presence of an additional free-wall pathway in four of six patients. In two of these four patients, maximal preexcitation showed a typical posteroseptal pattern, and retrograde preexcitation occurred solely over the posteroseptal pathway. This finding suggests that, in some instances, the standard electrocardiogram may be less sensitive than phase analysis in detecting areas of ventricular preexcitation. Similar observations were reported by Chan et al.¹² It should be emphasized that phase analysis is truly complementary to invasive studies in that it allows for mapping of ventricular preexcitation. In contrast, invasive studies are designed to accurately locate the atrial insertion site of the extranodal pathway. Correct definition of pathway location by endocardial recordings may be difficult, for example, in a patient who has dual pathways with sole retrograde conduction over only one.

Conclusions

This study documents the limitations of using either invasive or noninvasive data in predicting ablation outcome for patients with posteroseptal pathways. The presence of the typical posteroseptal pattern on electrocardiograms during maximal preexcitation failed to predict ablation outcome. Deviations from the typical posteroseptal electrocardiogram pattern were highly indicative of the presence of an additional accessory pathway.

Similarly, the VA interval during orthodromic tachycardia failed to predict successful ablation.

While the correlation between specific phase patterns and ablation outcome was poor, a concentric peripheral pattern with synchronous ventricular activation proved to be highly specific but very insensitive for predicting successful ablation. Phase analysis is helpful in corroborating the presence of additional pathways and detecting pathways not identifiable by endocardial recordings.

References

1. Scheinman MM, Morady F, Hess DS, et al. Catheter induced ablation of the atrioventricular function to control refractory supraventricular tachycardia. *J Am Med Assoc* 1982; 248:851-855.
2. Gallagher JJ, Svenson RH, Kasell JH, et al. Catheter technique for closed-chest ablation of the atrioventricular conduction system. *N Engl J Med* 1982; 306:194-200.
3. Scheinman MM. Catheter ablation for patients with cardiac arrhythmias. *PACE* 1986; 9:551-564.
4. Holt PM, Boyd ECGA, Crick JCP, et al. Low energies and helifix electrodes in the successful ablation of atrioventricular conduction. *PACE* 1985; 8:639-645.
5. Fisher JD, Brodman R, Kim SG, et al. Attempted non-surgical electrical ablation of accessory pathways via the coronary sinus in the Wolff-Parkinson-White syndrome. *J Am Coll Cardiol* 1984; 4:685-694.
6. Morady F, Scheinman MM, Kou WH, et al. Long-term results of catheter ablation of a posteroseptal accessory atrioventricular connection in 48 patients. *Circulation* 1989; 79:1160-1170.
7. Gallagher JJ, Sealy WC, Kasell J, et al. Multiple accessory pathways in patients with pre-excitation syndrome. *Circulation* 1976; 54:571-591.
8. Smith WM, Gallagher JJ, Kerr CR, et al. The electrophysiologic basis and management of symptomatic recurrent tachycardia in patients with Ebstein's anomaly of the tricuspid valve. *Am J Cardiol* 1982; 49:1223-1234.
9. Morady F, Scheinman MM, DiCarlo LA, et al. Coexistent posteroseptal and right-sided atrioventricular bypass tracts. *J Am Coll Cardiol* 1985; 5:640-646.
10. Gallagher JJ, Pritchett ELC, Sealy WC, et al. The preexcitation syndromes. *Prog Cardiovasc Dis* 1978; 20:285-327.
11. Botvinick E, Fraiss M, O'Connell W, et al. Phase image evaluation of patients with ventricular preexcitation syndromes. *J Am Coll Cardiol* 1984; 3:799-814.
12. Chan WWC, Kalff V, Dick M, et al. Topography of preempting ventricular segments in patients with Wolff-Parkinson-White syndrome using scintigraphic phase mapping and esophageal pacing. *Circulation* 1983; 67:1139-1146.

13. Nakajima K, Bunko H, Tada A, et al. Nuclear tomographic phase analysis: Localization of accessory pathway in patients with Wolff-Parkinson-White syndrome. *Am Heart J* 1985; 109:809-815.
14. Botvinick E, Frais M, Shosa D, et al. An accurate means of detecting and characterizing abnormal patterns of ventricular activation by phase image analysis. *Am J Cardiol* 1982; 50:289-298.
15. Bardy GH, Ivey TD, Coltari F, et al. Developments, complications and limitations of catheter-mediated ablation of posterior accessory atrioventricular pathway. *Am J Cardiol* 1988; 61:309-316.
16. Ruder MA, Mead RH, Gaudiani V, et al. Transvenous catheter ablation of extranodal accessory pathways. *J Am Coll Cardiol* 1988; 11:1245-1253.
17. Warin JF, Haissaguerre M. Fulguration of accessory pathways in any location: report of seventy cases. *PACE* 1989; 12:215-218.
18. Borggreffe M, Budde T, Podczeck A, et al. High frequency alternating current ablation of an accessory pathway in humans. *J Am Coll Cardiol* 1987; 10:576-582.
19. Kuck KH, Kunze KP, Schlüter M, et al. Modification of a left-sided accessory atrioventricular pathway by radiofrequency current using a bipolar epicardial-endocardial electrode configuration. *Eur Heart J* 1988; 9:927-932.
20. Jackman W, Wang X, Moulton K, et al. Role of coronary sinus in radiofrequency ablation of left free-wall accessory AV pathways. (abstract) *Circulation* 1990; 82:III-689.
21. Kuck KH, Schlüter M, Geiger M, et al. Radiofrequency current approach to successful catheter ablation of accessory pathways. (abstract) *Circulation* 1990; 82:III-689.
22. Langberg JJ, Chin MC, Rosenqvist M, et al. Catheter ablation of the atrioventricular junction with radiofrequency energy. *Circulation* 1989; 80:1527-1535.
23. Jackman WM, Friday KJ, Fitzgerald DM, et al. Localization of left free-wall and posteroseptal accessory atrioventricular pathways by direct recording of accessory pathway activation. *PACE* 1989; 12:204-214.
24. Cox JL, Gallagher JJ, Cain ME. Experience with 118 consecutive patients undergoing operation for the Wolff-Parkinson-White syndrome. *J Thorac Cardiovasc Surg* 1985; 90:490-501.
25. Selle JG, Sealy WC, Gallagher JJ, et al. The complex posterior septal space in the Wolff-Parkinson-White syndrome. Surgical experience with 47 patients. *J Thorac Cardiovasc Surg* 1989; 37:299-304.
26. Guiraudon GM, Klein GJ, Sharma AD, et al. "Atypical" posteroseptal accessory pathway in Wolff-Parkinson-White syndrome. *J Am Coll Cardiol* 1988; 12:1605-1608.
27. Winters SL, Gomes A. Intracardiac electrode catheter recordings of atrioventricular bypass tracts in Wolff-Parkinson-White syndrome: Techniques, electrophysiologic characteristics and demonstration of concealed and decremental propagation. *J Am Coll Cardiol* 1986; 7:1392-1403.
28. Benson DW, Sterba R, Gallagher JJ, et al. Localization of the site of ventricular preexcitation with body surface maps in patients with Wolff-Parkinson-White syndrome. *Circulation* 1982; 65:1259-1268.
29. Kamakura S, Shimomura K, Ohe T, et al. The role of initial minimum potentials on body surface maps in predicting the site of accessory pathways in patients with Wolff-Parkinson-White syndrome. *Circulation* 1986; 74:89-96.
30. Bockeria LA, Revishvily AS, Poljakova IP. Body surface mapping and nontraditional ECG leads in patients with Wolff-Parkinson-White syndrome. *PACE* 1990; 13:1110-1115.
31. Reddy GV, Schamroth L. The localization of bypass tracts in the Wolff-Parkinson-White syndrome from the surface electrocardiogram. *Am Heart J* 1987; 113:984-993.
32. Packer DL, Ellenbogen KA, Colavita PG, et al. Utility of introducing ventricular premature complexes during reciprocating tachycardia in specifying the location of left free wall accessory pathways. *Am J Cardiol* 1989; 63:49-57.
33. Botvinick E, Schechtmann N, Dae M, et al. Augmented preexcitation assessed by scintigraphic phase analysis during atrial pacing. *Am Heart J* 1987; 114:738-745.
34. Bashore TM, Stine RA, Shaffer PB, et al. The non-invasive localization of ventricular pacing sites by radionuclide phase imaging. *Circulation* 1984; 70:681-694.