Effect of Radiofrequency Catheter Ablation on Doppler Echocardiographic Parameters in Patients With Wolff-Parkinson-White Syndrome

Nazmiye ÇAKMAK,¹ MD, Mahmut ÇAKMAK,¹ MD, Ahmet AKYOL,¹ MD, Enis OGUZ,¹ MD, Nurten SAYAR,¹ MD, Abdurrahman EKSIK,¹ MD, Ahmet ALPER,¹ MD, Hakan HASDEMİR,¹ MD, Hale YILMAZ,¹ MD, İzzet ERDİNLER,¹ MD, and Kadir GURKAN,¹ MD

SUMMARY

The aim of this study was to compare the conventional Doppler echocardiographic parameters before and after accessory pathway ablation in patients with Wolff-Parkinson-White (WPW) syndrome. Thirty patients (19 males, 11 females) aged 35.5 ± 14.4 years were enrolled in the study. All patients underwent successful radiofrequency catheter ablation (RFCA). Echocardiographic examination was performed before and after RFCA. Aortic and pulmonary flows, diastolic early (E) and late (A) transmitral filling velocities, their velocity time integrals (VTI), mitral diastolic filling time (DFT), deceleration time (DT), isovolumic relaxation time (IVRT), aortic ejection time, and aortic VTI were assessed before and after RFCA. We found that the pulmonary valve opened earlier than the aortic valve when the accessory pathway was located on the right ventricular side ($P = 0.02$). Otherwise, if the accessory pathway was located on the left ventricular side, the aortic valve opened earlier ($P < 0.01$). Intervals between the onsets of aortic and pulmonary flows were shortened after RFCA ($P = 0.01$). We also observed prolongation of DFT ($P < 0.001$), increases in A velocity ($P < 0.05$) and its VTI ($P < 0.01$), as well as a decrease in the E/A ratio ($P < 0.01$) and shortening of aortic ejection time ($P = 0.01$) with restoration of AV conduction. We conclude that Doppler echocardiographic examination can provide clues about accessory pathway location and RFCA causes some significant changes in Doppler echocardiographic time intervals. These changes confirm that cardiac synchrony is restored after RFCA. (Int Heart J 2007; 48: 165-175)

Key words: Wolff-Parkinson-White syndrome, Radiofrequency catheter ablation, Doppler echocardiography

RADIOFREQUENCY catheter ablation (RFCA) has been established as a curative treatment for patients with Wolff-Parkinson-White (WPW) syndrome in

From the ¹ Department of Cardiology, Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Center, Istanbul, Turkey.

Address for correspondence: Nazmiye Çakmak, MD, Department of Cardiology, Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Center, Daye Kadın Sok. Fuze Apt. No: 29/6 34668 Üsküdar, Istanbul, Turkey.

Received for publication October 11, 2006.

Revised and accepted January 22, 2007.

recent years. Estimating the location of the accessory pathway before the procedure is helpful for catheter mapping to determine a precise ablation site and for shortening the time required for ablation. Several noninvasive methods of estimating the location of the accessory pathway have been proposed. Delta wave polarity or QRS polarity on a 12 lead ECG has been widely used to determine accessory pathway location.¹⁻⁵⁾ Related to echocardiography, M-mode echocardiography,⁶⁻⁸⁾ phase analysis of echocardiographic images,^{9,10)} Doppler tissue imaging,^{11,12)} and Doppler myocardial imaging¹³⁾ have also been employed to detect the accessory pathway side. These methods have focused mainly on abnormal ventricular motion. It can be hypothesized that when electric currents through the normal and accessory pathways reach the left ventricular (LV) wall, asynchronous systolic LV motion occurs. It is also reasonable to assume that the location and degree of asynchronous wall motion depends on the accessory side.¹⁴⁾ Cardiac synchrony is restored with abolition of the accessory pathway and normalization of the AV interval. The aim of this study was to compare systolic and diastolic conventional Doppler echocardiographic parameters before and after RFCA, concentrating on the onsets of aortopulmonary flows to detect the accessory pathway location and the restoration of cardiac synchrony.

METHODS

Study population: The study population consisted of 30 patients (19 males, 11 females, 35.5 ± 14.4 years) who had manifest accessory pathway. Exclusion criteria were the presence of any known cardiac or noncardiac disease, bundle branch block or AV conduction abnormalities on the ECG, a left ventricular ejection fraction lower than 50%, an abnormal diastolic transmitral pulsed-wave Doppler pattern, and multiple accessory pathways as assessed during electrophysiological study (EPS). The patients had undergone RFCA because of either drug refractoriness or clinical intolerable tachycardias. All patients had normal sinus rhythm during the study.

Echocardiography: Echocardiographic examination was performed on all patients before and 1 day after RFCA. Subjects were examined in the left lateral position with a GE Vivid 7 system (GE Vingmed Ultrasound A/S, Horten, Norway). A standard phased-array, 2.5 MHz transducer was used for 2-dimensional and Doppler imaging. Mitral inflow velocity patterns were recorded with the sample volume between the tips of the leaflets in the apical 4-chamber view. The QAV and QPV intervals were measured as the intervals between the time from the onset of the delta wave on the surface ECG to simultaneously recorded onset of aortic flow and the time from the beginning of the delta wave to the onset of pulmonary artery flow, respectively. ΔQV_R and ΔQV_L intervals were calculated

as the differences between QAV and QPV intervals ($\Delta QV_R = QAV - QPV$ in right-sided accessory pathway location and $\Delta QV_L = QPV - QAV$ in left-sided accessory pathway location). The means of ΔQV_R and ΔQV_L (ΔQV) were compared between the preablation and postablation periods. The QPV interval was measured on the pulmonary leaflets in the parasternal short axis. The QAV interval, aortic ejection time, and aortic VTI were measured on the aortic leaflets in an apical 3- or 5-chamber view. Aortic ejection time was calculated by measuring the time from aortic valve opening to aortic valve closure. IVRT was obtained by angulating the pulsed-Doppler beam toward the LV outflow velocities and thus measuring the interval from cessation of aortic flow to onset of mitral inflow. All of these pulsed-wave Doppler tracings with simultaneous ECG were recorded at a sweep speed of 100 mm/sec. Three consecutive cycles were digitally stored, measured off-line, and averaged for each parameter by both investigators for each of the required views and modalities. Measurements were made according to the recommendations of the American Society of Echocardiography for quantification of Doppler echocardiography.¹⁵⁾ All of the measurements were performed by 2 independent and experienced echocardiographers. Each of the investigators was blinded to the measurements of the other. Parameters measured were the following: QPV and QAV intervals, E wave velocity and its VTI, A wave velocity and its VTI, DFT (E + A duration), DT, IVRT, aortic ejection time, and aortic VTI. Echocardiographic data were digitally stored and independently analyzed by 2 investigators with an interobserver variability of 5%. Reported values are the average of the 2.

Electrophysiological study and ablation procedure: EPS and simultaneously RFCA were performed on each patient after obtaining informed, written consent. Antiarrhythmic agents were discontinued in all patients, for at least 5 half-lives before the invasive EPS and RFCA. EPS was performed using 3 diagnostic electrodes introduced under fluoroscopic guidance. Quadripolar electrodes were introduced via femoral veins into the His-bundle area (His-bundle electrode [HBE]) and the right ventricle apex (RVA). A third decapolar diagnostic electrode, recording unipolar and bipolar signals from the coronary sinus, was introduced via the right femoral vein also. Catheter ablation was performed by the conventional method using a transaortic approach via the right femoral artery on the left-sided and a right transatrial approach via the right femoral vein on the right-sided accessory pathways. Temperature-controlled radiofrequency energy (20-30 W) was delivered by the ablation system using a 7 French deflectable electrode catheter with a 4 mm tip and 2.5 mm interelectrode spacing (Medtronic RF Mariner). The RF current was supplied by a 484 kHz generator (Medtronic Atakr II, Medtronic Inc, MN, USA). Data were displayed and recorded using an electrophysiological monitoring system (Quinton Electrophysiology Corp., Seat-

tle, WA, USA). The location of the accessory pathway was defined by standard techniques involving (1) identification of the shortest atrioventricular time in sinus rhythm, (2) mapping of the shortest ventriculoatrial conduction time during ventricular pacing or orthodromic reciprocating tachycardia, and (3) identification of an accessory pathway potential. The location of the accessory pathway was confirmed as a successful ablation site.

Statistical analysis: All continuous parameters are expressed as the mean $\pm$ SD. To compare the differences between preablation and postablation parameters, the paired Student *t*-test was used, while for comparison of the QAV and QPV intervals in right and left-sided accessory pathway location the unpaired Student *t*-test was used. All statistical analyses were performed using a computer software package with SPSS modality. *P* values less than 0.05 were considered as the level of statistical significance in all analyses.

RESULTS

The clinical and 2-dimensional echocardiographic features of the study population are summarized in Table I.

Electrophysiological findings: According to the EPS data, the accessory pathways were located on the right side of the heart in 16 patients (53%) and on the left side in 14 patients (47%). The locations of the accessory pathways were as follows: Right posterior septum in 7, right posterior in 2, right mid septum in 1, right lateral in 2, right anterior septum in 2, ostium of the coronary sinus in 2, left lateral in 7, left posterior septum in 2, left anterior lateral in 2, left anterior in 1,

Table I. Clinical and Two-Dimensional Echocardiographic Characteristics of the Study Population

	Patients (<i>n</i> = 30)
Age (years)	35.5 $\pm$ 14.4
Female	11 (37%)
Male	19 (63%)
Atrial fibrillation	15 (50%)
AVRT	15 (50%)
Left atrial dimension (cm)	3.4 $\pm$ 0.5
Right atrial dimension (cm)	3.3 $\pm$ 0.4
Interventricular septum (cm)	0.91 $\pm$ 0.1
Posterior wall (cm)	0.89 $\pm$ 0.2
Left ventricular diastolic diameter (cm)	4.7 $\pm$ 0.4
Left ventricular systolic diameter (cm)	3.1 $\pm$ 0.5
Left ventricular ejection fraction (%)	65.8 $\pm$ 4.8

AVRT indicates atrioventricular reentrant tachycardia. All data are expressed as the mean $\pm$ SD.

Table II. Summary of Doppler Echocardiographic Parameters Before and After RFCA

	Preablation	Postablation	<i>P</i>
R-R (ms)	810 ± 148	798 ± 165	NS
E (cm/s)	70 ± 14	65 ± 13	NS
A (cm/s)	50 ± 10	60 ± 12	< 0.05
E/A ratio	1.4 ± 0.5	1.1 ± 0.4	< 0.01
E VTI (cm)	11.5 ± 2.1	12 ± 2.4	NS
A VTI (cm)	6.2 ± 1.4	7.2 ± 1.6	< 0.01
Mitral DFT (ms)	440 ± 92	457 ± 98	< 0.001
DT (ms)	150 ± 20	154 ± 16	NS
IVRT	72 ± 10	68 ± 14	NS
Aortic VTI (cm)	24 ± 3.9	22 ± 4.0	NS
Aortic ET (ms)	268 ± 32	252 ± 33	0.01
Right-sided accessory pathway			
QPV interval (ms)	114 ± 26	93.6 ± 14	< 0.001
QAV interval (ms)	135 ± 21	107 ± 11	< 0.001
Left-sided accessory pathway			
QPV interval (ms)	131 ± 14	106 ± 19	< 0.001
QAV interval (ms)	112 ± 20	90.4 ± 20	< 0.001
ΔQV interval (ms)	21.5 ± 14.2	14 ± 6.9	0.01

RFCA indicates radiofrequency catheter ablation; R-R, R-R interval; VTI, velocity time integral; DFT, diastolic filling time; DT, deceleration time; IVRT, isovolumic relaxation time; ET, ejection time; and ΔQV interval, interventricular electromechanical delay. All data are expressed as the mean ± SD.

Figure 1. Pulsed-Doppler recordings of pulmonary and aortic valve flows, respectively, in a patient with right-sided accessory pathway location before RFCA. QPV interval (A) was shorter than QAV interval (B).

left posterior in 1, and left posterior lateral in 1. After successful RFCA, no ventricular preexcitation or inducible supraventricular tachyarrhythmias could be recorded and no complications were present.

Doppler echocardiographic findings: Doppler echocardiographic parameters before and after RFCA therapy are listed in Table II. QPV and QAV intervals were shortened in the postablation period (114 ± 26 ms versus 93.6 ± 14 ms, $P <$

Figure 2. Pulsed-Doppler recordings of aortic and pulmonary valve flows, respectively, in a patient with left-sided accessory pathway location before RFCA. QAV interval (A) was shorter than QPV interval (B).

0.001, and 135 ± 21 ms versus 107 ± 11 ms, $P < 0.001$, respectively, in right-sided accessory pathway, and 131 ± 14 ms versus 106 ± 19 ms, $P < 0.001$, and 112 ± 20 ms versus 90.4 ± 20 ms, $P < 0.001$, respectively, in left-sided accessory pathway locations) due to delta wave disappearance on the ECG. As seen in Table II, the QPV interval was shorter than the QAV interval in the right-sided accessory pathway location (114 ± 26 ms versus 135 ± 21 ms, $P = 0.02$) in the preablation period and (93.6 ± 14 ms versus 107 ± 11 ms, $P = 0.03$) in the postablation period. This means that the pulmonary valve opens earlier than the aortic valve if the accessory pathway is located on the right ventricular side (Figure 1). In the left-sided accessory pathway location, the QAV interval was shorter than the QPV interval (112 ± 20 ms versus 131 ± 14 ms, $P < 0.01$) in the preablation and (90.4 ± 20 ms versus 106 ± 19 ms, $P = 0.03$) postablation periods. In other words, the aortic valve opens earlier than the pulmonary valve if the accessory pathway is located on the left ventricular side (Figure 2). The Δ QV interval (interventricular electromechanical delay) was significantly shortened in the postablation period (21.5 ± 14.2 ms versus 14.0 ± 6.9 ms, $P = 0.01$). Although E velocity, E VTI, DT, IVRT, and aortic VTI measurements did not show any statistical significance, A velocity (50 ± 10 cm/s versus 60 ± 12 cm/s, $P < 0.05$), A VTI (6.2 ± 1.4 versus 7.2 ± 1.6 , $P < 0.01$), and DFT (440 ± 92 ms versus 457 ± 98 ms, $P < 0.001$) measurements were significantly increased and aortic ejection time (268 ± 32 ms versus 252 ± 33 ms, $P = 0.01$) and E/A ratio (1.4 ± 0.5 versus 1.1 ± 0.4 , $P < 0.01$) were significantly decreased in the postablation period.

DISCUSSION

In this study, we used conventional Doppler echocardiography and we compared Doppler echocardiographic parameters before and after RFCA in patients

with WPW syndrome. The results indicated that these parameters can provide information about accessory pathway location focusing on the onsets of the aortopulmonary flows as well as about the restoration of cardiac synchrony using QAV and QPV intervals.

There have not been any studies analyzing the location of the accessory pathway using conventional Doppler echocardiographic parameters. Normally, the aortic valve opens 6 ms earlier than the pulmonary valve. Ventricular activation and contraction features with aortopulmonary valve opening sequences are changed in several situations, such as left bundle branch block (LBBB) and right apical pacing as well as WPW syndrome. In LBBB or right ventricular apical pacing, LV activation follows right ventricular activation with transmyocyte stimulus distribution and the His-Purkinje system. Left ventricular contraction starts 85 ms after right ventricular contraction. The opening and closing of the aortic and mitral valves occur later than that of the pulmonary and tricuspid valves. These conditions result in interventricular asynchronous contractions.¹⁶⁾ Accessory pathways insert into the atrial and basal ventricular myocardium. In the presence of an accessory pathway, depolarized basal myocardium and aortopulmonary valves sites, which normally are depolarized last, are depolarized first.¹⁷⁾ Therefore, the pulmonary valve opens earlier in right-sided accessory pathway, and the aortic valve opens earlier in left-sided accessory pathway locations. We expected restoration of the normal aortopulmonary valve opening sequence in right-sided accessory pathway location after RFCA. We did not observe the restoration of this sequence after RFCA. This was interpreted as being due to some kind of remodelling that had developed with time. Further long-term studies are needed to establish whether this remodelling may reverse or not.

Preexcitation, in addition to short AV delay, is associated with asynchronous interventricular and intraventricular contractions. When the accessory pathway is located on the right ventricular side, electric current along the accessory pathway reaches the LV wall during the systolic phase late because the pathway is located remote from the LV wall and propagation of the electric wave in this chamber by the accessory pathway is slight. When the accessory pathway is located on the LV side, electric current along the accessory pathway and through the normal conduction system reaches the LV wall with closely related timing during the systolic phase.¹⁴⁾ In our study, interventricular electromechanical delay was evaluated using the delay between the onsets of the pulmonary and aortic flows in the pre- and postablation periods (Δ QV interval). We found that the Δ QV interval was significantly shortened after RFCA. This indicates that interventricular synchrony was apparently restored after RFCA. Because interventricular and intraventricular asynchrony are decreased after RFCA, LV contracts more effectively. Thus,

the aortic ejection time is shortened. Although the concept of interventricular electromechanical delay was used in cardiac resynchronization therapy (CRT), this study is the first to demonstrate interventricular asynchrony in connection with conventional Doppler echocardiographic parameters in patients with WPW syndrome. In patients suffering from severe systolic heart failure, abnormal electrical conduction contributes to asynchrony between right and LV contraction and discordant wall motion within the LV.^{18,19)} LBBB type conduction delay results in early activation of the LV septal wall and delayed activation of the LV free wall.^{20,21)} This intraventricular asynchrony leads to a delayed onset of relaxation, which results in shortening of diastole and impaired LV filling, which further aggravates LV dysfunction.^{22,23)} CRT with biventricular pacing has been recommended for patients with advanced chronic heart failure and wide QRS complex of LBBB morphology. This therapy has been shown to resynchronize contraction and to improve hemodynamics and clinical outcome.²⁴⁻²⁶⁾ CRT decreases the mitral E wave velocity and the E/A ratio. DFT is prolonged with an increase in mitral E wave duration. The prolongation of IVRT after CRT has also been observed.²⁷⁻²⁹⁾ CRT results in significant prolongation of aortic ejection time and an increase in aortic VTI.³⁰⁻³²⁾ Prolongation of DFT and aortic ejection time with a decrease in cardiac asynchrony lead to reductions in LV volumes and improvement in LV ejection fraction. Therefore, cardiac output and aortic VTI are increased.

Previous studies have showed that RFCA does not impair systolic function but does alter some diastolic parameters.^{33,34)} In this study, we found significant increases in A velocity, its VTI, and DFT, and a decrease in E/A after abolishing the accessory pathway. There were no changes in E velocity, its VTI, DT, and IVRT. The present results were also in agreement with those of Jue, *et al* who investigated the effect of preexcitation on Doppler indexes of left ventricular filling. They found a significant increase in late diastolic filling, with restoration of AV conduction, while there were no changes in the early filling velocity or its VTI, DT, or IVRT.³³⁾ Eksik, *et al* found that cE/A was decreased and cDT and cIVRT were increased after RFCA. However, their study population had various types of tachyarrhythmias.³⁴⁾ Previous investigations with sequential AV pace-makers have demonstrated that a short AV delay is associated with a reduced A wave velocity and atrial filling fraction. It has been postulated that because of interruption of active atrial transport by ventricular systole, atrial emptying is incomplete resulting in an increase in residual left atrial volume and pressure. There is a compensatory increase in E velocities. With a longer and appropriate AV delay, atrial emptying is more complete with a resultant increase in A wave velocity and atrial filling fraction, while the E wave correspondingly diminishes.³⁵⁻³⁷⁾ It might be possible to explain the changes in late diastolic filling

parameters by RFCA. RF energy produces thermal injury at the site where the catheter tip contacts cardiac tissue and causes an area of myocardial necrosis. Several biochemical parameters have also been validated in the diagnosis of this myocardial damage induced by RFCA.^{38,39)} Histologic examination of these lesions reveals coagulation necrosis with destruction of the myofibril architecture and contraction band necrosis.⁴⁰⁾ Coagulation necrosis and fibrosis in the atrium may lead to stiff atria with a subsequent increase in A velocity and its VTI.

Study limitations: One limitation of our study is that we compared Doppler parameters before and after RFCA therapy in an acute setting. Hence, the chronic effect of RFCA therapy on Doppler parameters could not be predicted in our study. The second limitation of our study is that we were unable to predict the accessory pathway sublocation by conventional Doppler echocardiography. For sublocation analysis, larger study groups are needed to define the cut-off points related to the time intervals of aortopulmonary valve opening.

Conclusions: The results of this study support the use of conventional Doppler echocardiography, which can be easily and reproducibly obtained, to detect accessory pathway location and the restoration of cardiac synchrony.

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