Chronic Frequent Premature Ventricular Complexes Originating From Right and Non-Right Ventricular Outflow Tracts

Change in Left Ventricular Function After Radiofrequency Catheter Ablation

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Summary

Frequent premature ventricular complexes (PVCs) from the right ventricular outflow tract (RVOT) have recently been reported to be a cause of dilated cardiomyopathy. We studied the clinical impact of the elimination of PVCs from RVOT and non-RVOT.

Thirty-six patients with symptomatic PVCs that were treated with radiofrequency catheter ablation (RFCA) were studied. The patients were assigned to one of two groups according to the origin of the PVCs (group I, RVOT-origin, n = 24; group II, non-RVOT-origin, n = 12) and observed for 10.5 ± 7.1 months.

The burden of PVCs at baseline was 19.7 ± 10.6% and 18.7 ± 8.7% in group I and group II, respectively (P = 0.779). In group II, hypertension was more common (16.7% versus 58.3%, P = 0.020) and LV diastolic function was worse (Em, 8.7 ± 3.0 versus 6.4 ± 1.8 cm/second, P = 0.018). The LV end diastolic volume index (LVEDVI) decreased in both groups (59.7 ± 14.6 to 50.9 ± 9.6 mL/m^2, P = 0.004 in group I; 60.0 ± 19.9 to 51.6 ± 12.4 mL/m^2, P = 0.044 in group II), while the left atrial volume index (LAVI) decreased only in group I (36.7 ± 11.7 to 31.7 ± 10.0 mL/m^2, P = 0.002 in group I; 35.6 ± 11.9 to 33.8 ± 10.3 mL/m^2, P = 0.317 in group II). The left ventricular ejection fraction (LVEF) significantly improved in both groups (51.1 ± 6.6 to 59.8 ± 7.2 %, P < 0.01 in group I; 49.9 ± 6.9 to 59.0 ± 5.9 %, P < 0.01 in group II).

RFCA of PVCs leads to a reduction of LV volume and improvement of LV systolic function regardless of the origin of the PVCs. Conversely, a non-RVOT-origin as well as an RVOT-origin of the PVCs can cause DCM-like changes in the left ventricle. (Int Heart J 2010; 51: 388-393)

Key words: Premature ventricular complex, Dilated cardiomyopathy, Radiofrequency catheter ablation, Right ventricular outflow tract, Left ventricular remodeling

Tachycardia induced cardiomyopathy (TIC) is recognized as a subtype of dilated cardiomyopathy (DCM), which is induced by persistent supraventricular or ventricular tachycardia and reversed by control of the tachyarrhythmias. Premature ventricular complexes (PVCs) are the most frequently encountered form of ventricular arrhythmia in clinical practice; they are even observed in healthy subjects. Although the prognosis of frequent PVCs has been considered generally benign, recent studies have suggested that long-standing frequent PVCs may cause progressive left ventricular (LV) systolic dysfunction and dilatation. In addition, there are reports that suppression of PVCs with antiarrhythmic drugs (AADs) or the radiofrequency catheter ablation (RFCA) of PVCs from right ventricular outflow tract (RVOT) can lead to a reduction in LV volume and improvement of the LV ejection fraction (LVEF).

The aim of this study was to assess the relationship between left ventricular function and the burden of PVCs and to evaluate the structural and functional characteristics of the left ventricle before and after the ablation of the PVCs according to their origin.

Methods

Study population: The medical records of 70 consecutive patients who underwent RFCA for frequent symptomatic PVCs from 2006 to 2009 were reviewed. Patients with moderate or severe valvular heart disease, signs of congestive heart failure, a history of frequent alcohol drinking, LV dysfunction with segmental wall motion abnormalities, infrequent PVCs less than 4% of the total heart beats during 24 hours, sustained or nonsustained supraventricular or ventricular tachycardia, atrial fibrillation/flutter, a permanent/temporary pacemaker, or a malignancy requiring chemotherapy were excluded and 24 patients refused to be enrolled in the study. Finally, 36 patients were retrospectively analyzed. Treadmill exercise electrocardiography (ECG) or coronary angiography was performed in patients with exertional dyspnea, chest pain, or multiple cardiovascular risk factors to exclude coronary artery obstructive

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disease.

ECG and echocardiography: Standard 12-lead surface electrocardio-graphy (ECG) was performed before and during treatment. The origin of the PVCs was determined first by a standard 12-lead surface ECG. PVCs with left bundle branch block (LBBB) or right bundle branch block (RBBB) morphology with positive deflection in the aVF lead were considered to originate from the right ventricle outflow tract (RVOT) or left ventricular outflow tract (LVOT), respectively (Figure 1).

The burden of PVCs was quantified by percentages using 24-hour Holter recordings in each patient. Follow-up Holter recordings were obtained when patients had recurrent symptoms or PVCs were detected in the standard 12-lead surface ECGs during routine follow-up.

Cardiac structure and function were evaluated by echocardiography at baseline and during follow-up after the RFCA. From the 2-dimensional Doppler echocardiography, the end diastolic/systolic left ventricular internal dimension and volume, left ventricular ejection fraction, mitral inflow velocity (E), velocity of mitral septal annular velocity (Em), and the ratio of E and Em (E/Em), left atrial size, and volume were measured. All values were obtained during sinus rhythm. In the cases with persistent bigeminal PVCs at baseline, the end-diastolic volume was obtained at the point of the R wave of the normal sinus QRS complex, and the end-systolic volume was obtained when the left ventricular volume was minimal before the PVC-induced left ventricular contraction began. The LVEF was calculated using the biplane Simpson method.

Mapping and catheter ablation procedures: Informed consent was obtained from all patients for every invasive procedure including the RFCA. Antiarrhythmic drugs (AADs) were discontinued more than 5 half-lives before the procedure. The multipolar electrode catheters were positioned at the right ventricular apex, the His bundle, and the high right atrium via the femoral veins. A retrograde aortic approach was used in cases of PVCs with right bundle branch block morphology. Programmed atrial and ventricular stimulation, with up to 4 extrastimuli, was performed to induce supraventricular and ventricular tachycardia depending on the patients' symptoms.

Intravenous administration of isoproterenol was required when few PVCs were present. Activation mapping was preferentially performed using a 4-mm tip ablation catheter with 2-5-2 mm interelectrode spacing; in addition, pace mapping was performed to ensure accurate determination of the origin of the PVCs. RFCA was performed at the point of earliest endocardial activation on the activation map or the best QRS morphology on the pace map. Ablation was performed when matched morphology ≥ 11 of 12 leads in the standard 12-lead ECG was achieved. The application was continued for at least 30 seconds and when the PVCs were abolished, further application was performed. All patients were observed overnight with continuous telemetry monitoring after the ablation.

Statistical analysis: Continuous variables are described as the mean ± 1 standard deviation and were compared with the Student's *t*-test or one-way ANOVA. Chi-square analysis or Fisher's exact test (if a cell size < 5) was used to compare discrete variables between the groups. A correlation coefficient was obtained to clarify the relationship between the PVC burden and the LV size and LVEF. Echocardiographic measurements before and after treatment were compared by the paired *t*-test. A value of $P < 0.05$ was considered statistically significant.

Results

The mean age of the patients was 43.8 ± 13.9 and 19 patients were female. All of the patients had intolerable symptoms attributable to frequent PVCs. Palpitations or a sensation of skipping heartbeats were reported in 24 patients and 12 patients reported atypical inexplicable chest discomfort or dyspnea on exertion. Either treadmill exercise testing or coronary angiography was performed to evaluate the exertional dyspnea or chest discomfort in 26 patients. Out of 20 patients who underwent treadmill exercise testing, 19 showed no sign of induced ischemia on the ECG. One patient who did not complete the treadmill exercise test underwent coronary angiography and had normal angiographic findings. Six patients underwent coronary angiography without treadmill exercise testing. Five patients were found to have normal coronary arteries and one patient had a mild stenosis of the right coronary artery.

On the standard surface ECGs, 25 patients had PVCs

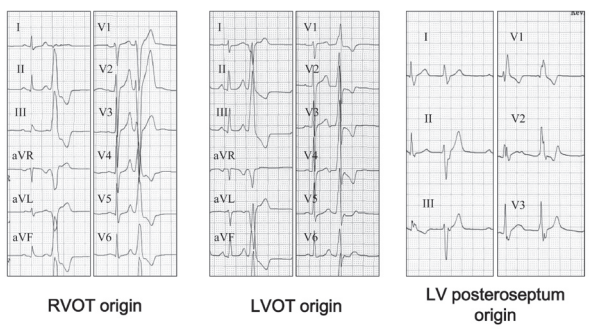

Figure 1. Standard 12-lead electrocardiography helps predict the origin of premature ventricular complexes (PVCs) before radiofrequency catheter ablation (RFCA). PVCs with positive deflection in the inferior leads are considered to originate from either of the ventricular outflow tracts.

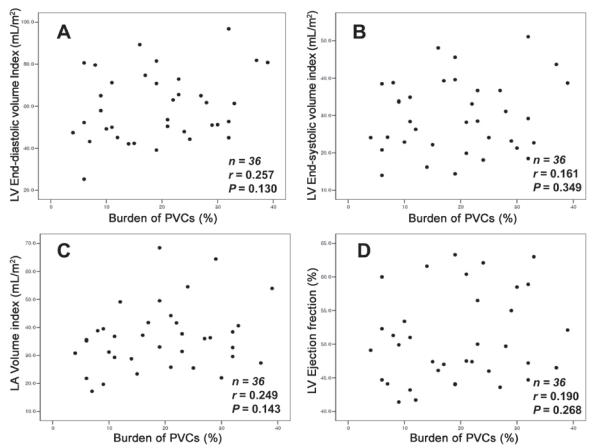

Figure 2. Correlation between the frequency of PVCs. **A:** left ventricular end-diastolic volume index (LVEDVI); **B:** left ventricular systolic volume index (LVESVI); **C:** left atrial volume index (LAVI); **D:** left ventricular ejection fraction (LVEF).

with left bundle branch block morphology, 8 with right bundle branch block morphology, and 3 with indeterminate morphology. Intracardiac electrography revealed 24 had RVOT origin PVCs (group I) and 12 had non-RVOT origin PVCs (group II) (Figure 2). Out of 12 non-RVOT PVCs, 9 were from the LVOT, and 3 were from the left anteroseptal free wall, right ventricular inflow tract near the His bundle and left ventricular posteroseptum. Follow-up echocardiography was performed 10.5 ± 7.1 months after the RFCA. Three patients had recurrent symptoms with frequent PVCs within 6 months after the procedure and underwent second ablation. There was no recurrence of frequent PVCs after second ablation.

Table I. Clinical Characteristics of the Patients With Frequent Premature Ventricular Complexes at Baseline

	Group I (RVOT) (n = 24) Mean ± SD	Group II (non RVOT) (n = 12) Mean ± SD	P
Age (years)	42.6 ± 15.3	46.1 ± 10.6	0.489
Male/Female	12/12	5/7	0.637
*Typical/Atypical symptoms	15/9	9/3	0.453
Duration of AAD prescription before RFCA (months)	5.9 ± 13.3	13.8 ± 12.7	0.102
DM (%)	1 (4.2%)	2 (16.7%)	0.201
Hypertension (%)	4 (16.7%)	7 (58.3%)	0.020
Burden of PVCs (%)	19.7 ± 10.6	18.7 ± 8.7	0.779
† ACEI/ARB (%)	4 (16.7%)	7 (58.3%)	0.020
† Calcium channel blocker (%)	1 (4.2%)	3 (25.0%)	0.098
† Beta blocker (%)	9 (37.5%)	8 (66.7%)	0.098
Follow-up duration after RFCA (months)	9.8 ± 7.4	11.8 ± 6.6	0.426

*Typical symptoms mean palpitations or skipped beats with/without chest pain or dyspnea on exertion, while atypical symptoms indicate chest pain or dyspnea on exertion. † Maintained medication after RFCA. AAD indicates antiarrhythmic drug; RFCA, radiofrequency catheter ablation; DM, diabetes mellitus; ACEI, angiotensin converting enzyme inhibitor; and ARB, angiotensin II receptor blocker.

Baseline characteristics: The patient age, gender, number of PVCs, and duration of AADs prescribed did not differ between the two groups (Table I). The frequency of hypertension was greater in group II (16.7% versus 58.3%, P = 0.020) and the use of renin-angiotensin-aldosterone cascade blocking drugs such as angiotensin converting enzyme inhibitors (ACEIs) or angiotensin receptor blockers (ARBs) was more frequent in group II (16.7% versus 58.3%, P = 0.020). There was no difference between the groups with regard to the use of calcium channel blockers or beta-blockers. The indications for RFCA were as follows: 32 patients had PVC-related symptoms that were not suppressed with AADs, two patients could not tolerate the side effects of the AADs, and one female patient was planning a pregnancy and refused AADs.

Echocardiographic changes: At baseline, there was no difference in the LV end-diastolic volume index (LVEDVI), LV end-systolic volume index (LVESVI), LV ejection fraction (LVEF), or LA volume index (LAVI) between the groups. The mitral septal annular velocity (Em) was lower in group II than in group I (Em; 8.7 ± 3.0 versus 6.4 ± 1.8 cm/second, P = 0.018) at baseline. Therefore, the E/Em representing left atrial wedge pressure was higher in group II (7.4 ± 2.5 versus 9.8 ± 3.7, P = 0.027) (Table II).

At baseline, significant correlations between the burden of PVCs and LVEDVI, LVESVI, LAVI, and LVEF were not observed (Figure 2).

In the entire subject population (n = 36, group I+II), there were significant reductions in the left ventricular volume (LVEDVI, 59.8 ± 16.3 to 51.1 ± 10.5 mL/m^2, P < 0.01) and left atrial volume (LAVI, 36.4 ± 11.6 to 32.4 ± 10.0 mL/m^2, P < 0.01) and improvement of the LV systolic function (LVEF, 50.7 ± 6.6 to 59.5 ± 6.7 %, P < 0.01) after the RFCA. With regard to LV diastolic function, there was a marginal reduction of Em (7.9 ± 2.9 to 7.2 ± 2.0 cm/second, P = 0.079) (Data not

Table II. Follow-Up Hemodynamic Changes Assessed by Echocardiography After RFCA

	Group I (n=24)			Group II (n = 12)		
	Baseline Mean ± SD	Follow-up Mean ± SD	P	Baseline Mean ± SD	Follow-up Mean ± SD	P
LVIDD (mm)	52.1 ± 5.0	48.9 ± 4.8	0.000	51.4 ± 4.5	49.2 ± 4.5	0.101
LVIDS (mm)	34.8 ± 5.8	31.3 ± 4.9	0.000	36.3 ± 4.0	32.4 ± 4.8	0.010
Fractional shortening (%)	33.5 ± 6.7	35.9 ± 8.2	0.206	29.1 ± 8.4	34.2 ± 8.4	0.130
LA diameter (mm)	35.8 ± 4.3	34.5 ± 3.9	0.016	38.4 ± 4.8	37.0 ± 4.8	0.351
LVEDVI (mL/m^2)	59.7 ± 14.6	50.9 ± 9.6	0.004	60.0 ± 19.9	51.6 ± 12.4	0.044
LVESVI (mL/m^2)	29.3 ± 8.7	20.6 ± 5.8	0.000	30.6 ± 12.0	21.1 ± 5.8	0.005
LVEF (%)	51.1 ± 6.6	59.8 ± 7.2	0.000	49.9 ± 6.9	59.0 ± 5.9	0.000
LA volume index (mL/m^2)	36.7 ± 11.7	31.7 ± 10.0	0.002	35.6 ± 11.9	33.8 ± 10.3	0.317
E (cm/second)	54.1 ± 21.3	56.2 ± 15.6	0.607	53.2 ± 17.2	54.8 ± 10.2	0.779
Em (cm/second)	*8.7 ± 3.0	7.5 ± 2.2	0.019	6.4 ± 1.8	6.6 ± 1.3	0.646
E/Em	*7.4 ± 2.5	7.9 ± 2.4	0.385	9.8 ± 3.7	8.5 ± 2.1	0.319
Deceleration time (msec)	215.2 ± 72.8	208.2 ± 56.5	0.616	207.4 ± 41.3	223.8 ± 58.4	0.459
† PA systolic pressure (mmHg)	30.6 ± 3.7	27.6 ± 4.4	0.086	29.5 ± 4.6	28.1 ± 3.4	0.742

* P < 0.05, versus Group II. † RVOT origin PVCs; n = 11, non-RVOT-origin; n = 7. LVIDD indicates left ventricular internal dimension at end diastole; LVIDS, left ventricular internal dimension at end systole; LVEDVI, left ventricular end diastolic volume index; LVESVI, left ventricular end systolic volume index; LVEF, left ventricular ejection fraction; E, velocity of early diastolic mitral inflow; and Em, velocity of early diastolic mitral septal annulus. P = baseline versus follow-up.

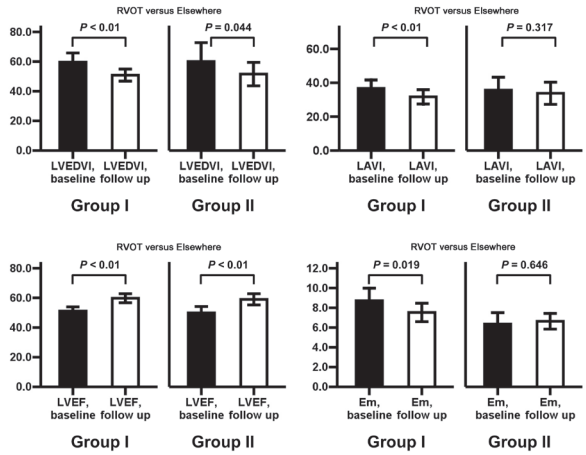

Figure 3. Changes in LV volume, LA volume, LVEF, and Em before and after RFCA. Analyses in group I and II were performed separately.

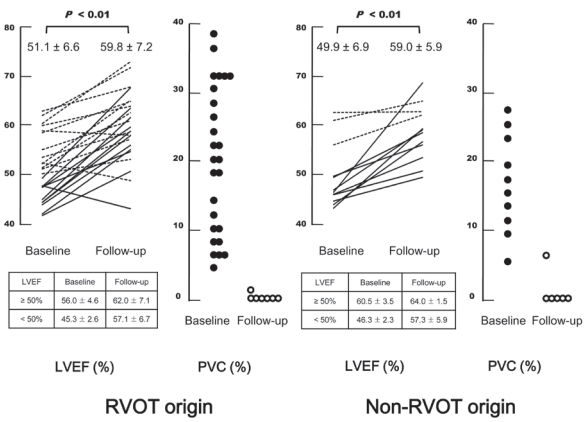

Figure 4. Changes in LVEF and the frequency of PVCs after treatment in both groups. The dotted lines indicate baseline LVEF 50% and the solid lines indicate baseline LVEF < 50%. Follow-up Holter recordings were performed when patients had recurrent symptoms or PVCs on standard 12-lead surface ECGs.

in the table).

Next, each group was individually analyzed. Regardless of the origin of the PVCs, there was a significant reduction of the LVEDVI in each group (group I; 59.7 ± 14.6 to 50.9 ± 9.6 mL/m^2, $P < 0.01$, group II; 60.0 ± 19.9 to 51.6 ± 12.4 mL/m^2, $P = 0.044$) and improvement of the LVEF (group I; 51.1 ± 6.6 to 59.8 ± 7.2 %, $P < 0.01$, group II; 49.9 ± 6.9 to 59.0 ± 5.9 %, $P < 0.01$) after RFCA (duration of follow-up: 10.5 ± 7.1 months). The LAVI decreased only in group I (group I, 36.7 ± 11.7 to 31.7 ± 10.0 mL/m^2, $P < 0.01$; group II, 35.6 ± 11.9 to 33.8 ± 10.3 mL/m^2, $P = 0.317$) (Table II, Figure 3). The Em decreased significantly in group I, whereas it was not changed in group II (Group I, 8.7 ± 3.0 versus 7.5 ± 2.2 cm/second, $P = 0.019$; Group II, 6.4 ± 1.8 versus 6.6 ± 1.3 cm/second, $P = 0.646$).

The entire subject population ($n = 36$, group I + II) was subdivided according to the baseline LVEF (below and above 50% of LVEF). The improvement in the LVEF (ΔLVEF) was more prominent in patients with a baseline LVEF < 50%, compared to patients with a baseline LVEF ≥ 50% regardless of the PVCs origin (ΔLVEF, 11.8 ± 6.4 versus 6.0 ± 5.0 %, $P = 0.021$ in group I, 11.0 ± 6.0 versus 3.5 ± 3.1%, $P = 0.070$ in group II). Neither the ΔLVEDVI nor ΔLAVI was influenced by the baseline LVEF (Data not shown in the table).

Follow-up 24-hour Holter recordings were obtained in 13 patients because of palpitations. Among these 13 patients, 12 showed a markedly reduced PVC burden after the RFCA, from 19.2 ± 7.3% to less than 1% of the total number of heart beats. Significant PVC burden was still observed in a patient despite a marked decrease (from 14% to 7% of total heart beats) (Figure 4). Another 23 patients did not complain of symptoms after the RFCA; therefore, their prior symptoms were thought to be resolved.

Table III. Origins of PVCs in Group II Patients

Patient number	Origin of PVCs
Case 1	Mitral annulus
Case 2	Left anteroseptal free wall
Case 3	Supravalvular left coronary cusp
Case 4	Mitral annulus
Case 5	Epicardial basal anterior wall
Case 6	Supravalvular left coronary cusp
Case 7	Anterior interventricular vein
Case 8	Mitral annulus
Case 9	RV inflow tract near His bundle
Case 10	Left ventricular posteroseptum
Case 11	Supravalvular left coronary cusp
Case 12	Supravalvular left coronary cusp

The surface ECGs of cases 2, 9, and 10 did not have an inferior axis.

DISCUSSION

The results of this study demonstrated that the suppression of PVCs by RFCA improved left ventricular systolic function and exerted a beneficial effect on left ventricular remodeling. These effects were observed in patients with PVCs regardless of their origin.

PVC as a cause of idiopathic dilated cardiomyopathy: Dilated cardiomyopathy has been generally regarded as an incurable disease with a poor prognosis. However, a variety of supraventricular and ventricular tachyarrhythmias are thought to be reversible causes of DCM, and are referred to as tachycardia induced cardiomyopathy (TIC).[1-3] PVC is the most commonly encountered tachyarrhythmia in clinical practice. Although reports on the long-term outcomes of frequent PVCs have been inconsistent,[4-7] chronic frequent PVCs have recently been reported to be associated with ventricular dilatation and deterioration of ventricular systolic function, and have been suggested to be a potential cause of DCM with uncertain etiology.[8,9] In addition, repetitive monomorphic PVCs from the outflow tracts have been suggested to be in a continuum with the common pathophysiology of sustained repetitive monomorphic ventricular tachycardia and nonsustained ventricular tachycardia (NSVT).[10] Therefore, PVC-induced cardiomyopathy may be a subtype of TIC. However, the pathogenesis of PVC-induced cardiomyopathy has not yet been investigated in de-

tail.[11-14)]

In the current study, the relationship between left ventricular function and the burden of PVCs at baseline as well as the structural/functional changes of the left ventricle after RFCA of the PVCs were evaluated. A reduction of the left ventricular volume and improvement of LV systolic function were observed regardless of the origin of the PVCs. This beneficial effect of eliminating the PVCs, observed in this study, is consistent with the findings of previous studies and provides additional evidence that frequent PVCs may be a cause of TIC. Duffee, *et al* reported that suppression of frequent PVCs by antiarrhythmic drugs (AADs) resulted in functional recovery and the reverse remodeling of a dilated left ventricle.[15)] Some studies have reported that ablation of PVCs originating from the RV outflow tract resulted in reduction of the LV volume and improvement of the LV ejection fraction (LVEF).[16-20)]

The burden of PVCs has been reported to be correlated with the LVEF and known to be an independent predictive factor for worsening LV systolic function in patients with untreated frequent PVCs.[17,18,21)] However, the burden of PVCs was not correlated with the volume of the cardiac chambers or the LVEF in this study. The burden of PVCs can episodically increase or decrease without treatment, regardless of accompanying LV remodeling or LV systolic dysfunction,[7,21)] which might explain the discrepant relationship between the burden of PVCs and LVEF in this study. Sarrazin, *et al* reported that the burden of PVCs originating from myocardial scars was not correlated with the LVEF, the majority of the PVCs were not from the RVOT, and the heterogeneity of the origin of the PVCs might interfere with the correlation between the arrhythmic burden and LV systolic function.[22)] In our study, there was a significant number of patients with non-RVOT origin PVCs; the heterogeneous origin of PVCs might have confounded the correlation between the burden of PVCs and LVEF.

Apart from the change of the LV volume and the LV systolic function, change in the LA volume was not analogous. LA enlargement is known as an indicator of chronic LV diastolic dysfunction and subsequent pressure overloading in the LA. In this study, reduction of LAVI after RFCA of PVCs appeared less prominent compared with the change of LV volume in both groups because LA enlargement was a secondary change to LV diastolic dysfunction. Moreover, due to the small number of cases in group II, statistical significance was reached only in group I; although LAVI decreased with RFCA in both groups.

PVCs and hypertension: Adenosine sensitive ventricular tachycardia, also known as outflow tract ventricular tachycardia (OT-VT), is the most common form of idiopathic ventricular tachycardia in patients without structural heart disease. This ventricular tachyarrhythmia usually originates from the RVOT although it can originate from the LVOT in 10-15% of cases.[23)] Kim, *et al* reported that PVCs originating from the outflow tract may be on the same spectrum as the OT-VT.[10)]

In this study, patients with non-RVOT PVCs more frequently had hypertension. The Em was lower and the ratio of early diastolic mitral inflow velocity (E) and Em (E/Em) was higher in the patients with non-RVOT PVCS compared to patients with RVOT PVCs.[24)] The more frequent hypertension, higher wall tension, and subsequent endocardial fibrosis might predispose the myocardial substrate to frequent PVCs and play a role in destabilizing the myocardial cells in the LV outflow tract, especially from non-RVOT sources; however, a causal relationship has not been established.[25)]

OT-VT is clinically detected between 30 and 50 years of age in most cases. The trigger that stimulates OT-VT during this period has not yet been determined.[23)] On the other hand, the outflow tract origin PVCs, a probable subtype of the OT-VT, become clinically significant during this period as well; the ageing process, including endocardial fibrosis followed by LV diastolic dysfunction, may stimulate frequent PVCs.

To date, various non-RVOT sites that produce ectopic impulses have been identified; the superior basal region of the left interventricular septum, the aorto-mitral continuity, aortic coronary cusp, and mitral annulus and epicardial sites in the area of the great cardiac and anterior interventricular veins. In this study, 3 patients in group II had non-outflow tract origin PVCs; the LV posteroseptum, RV inflow tract near the His bundle, and LV anteroseptal free wall (Table III). All 3 patients showed improved LVEF after elimination of the PVCs and two patients had hypertension. It is possible that these two hypertensive patients had more factors predisposing to ectopic impulse formation in the LV endocardium.

In conclusion, RFCA can be recommended when frequent symptomatic PVCs are refractory to medical treatment or when medical treatment was contraindicated, especially when tachycardia induced cardiomyopathy was a likely diagnosis. Our results show the benefits of RFCA on frequent isolated PVCs and the associated LV dysfunction. The procedure was safely performed to eliminate PVCs from either of the outflow tracts.

Study limitations: From January 2006 to February 2009, 70 patients underwent RFCA for frequent PVCs in our institute. We failed to eliminate PVCs in one patient because the point of earliest endocardial activation was too close to the His bundle to ablate. Frequent PVCs recurred in 7 out of 70 patients (5 RVOT and 2 non-RVOT origin) and 6 patients underwent redo RFCA. During more than one-year follow-up, no patient who underwent redo RFCA had a recurrence of frequent PVCs. One patient developed cardiac tamponade but was successfully treated with pericardiocentesis. There were no complications other than cardiac tamponade. The success and complication rates for RFCA at our institute are comparable to that at other institutes.[16,18-20)] We excluded as many patients with potential confounding factors as possible and only 36 patients were analyzed in the current study. The strict exclusion of patients with potential confounding factors is a merit of this study, while the small sample size is a major limitation.

Since the frequency of PVCs is so variable and can vary by as much as 5-40%, even in the same patient, the PVC burden from a single Holter recording does not accurately represent the full burden of PVCs. Assessment with repeated Holter recordings could have provided more reliable information.[21)] The temporal relationship between the initiation of frequent PVCs and the onset of cardiomyopathy is unknown in the majority of patients, which could have affected the extent of LV remodeling and functional deterioration. Not all of the patients were followed-up with Holter recordings. However, the spot checks with long-strip standard ECGs showed no PVCs and no further Holter recordings were required in these patients.

Conclusions: The results of this study showed that suppression of frequent PVCs by RFCA reduced the volume of the cardiac chambers regardless of whether the PVCs were from the RVOT or non-RVOT. The burden of PVCs was correlated with

neither the volume of the cardiac chambers nor the LVEF. The beneficial effects of RFCA, in patients with frequent PVCs, support the findings that repetitive isolated PVCs can cause cardiomyopathy. Even though RFCA was a reliable and safe option for treatment in this study, whether RFCA can improve long-term outcome in patients with PVC induced cardiomyopathy remains to be confirmed.

REFERENCES

1. Calò L, De Ruvo E, Sette A, *et al*. Tachycardia-induced cardiomyopathy: mechanisms of heart failure and clinical implications. J Cardiovasc Med 2007; 8: 138-43. (Review)
2. Vijgen J, Hill P, Biblo LA, Carlson MD. Tachycardia-induced cardiomyopathy secondary to right ventricular outflow tract ventricular tachycardia: improvement of left ventricular systolic function after radiofrequency catheter ablation of the arrhythmia. J Cardiovasc Electrophysiol 1997; 8: 445-50.
3. Kim YH, Goldberger J, Kadish A. Treatment of ventricular tachycardia-induced cardiomyopathy by transcatheter radiofrequency ablation. Heart 1996; 76: 550-2.
4. Ikegawa T, Chino M, Hasegawa H, *et al*. Prognostic significance of 24-hour ambulatory electrocardiographic monitoring in patients with dilative cardiomyopathy: a Prospective study. Clin Cardiol 1987; 10: 78-82.
5. Kaul U, Bharani AK, Malhotra A, Gopinath PG, Talwar KK, Bhatia ML. Prognostic implications of complex ventricular ectopy in patients with and without structural heart disease. Int J Cardiol 1987; 14: 79-89.
6. Kennedy HL, Whitlock JA, Spraque MK, Kennedy LJ, Buckingham TA, Goldberg RJ. Long-term follow-up of asymptomatic healthy subjects with frequent and complex ventricular ectopy. N Eng J Med 1985; 312: 193-7.
7. Gaita F, Giustetto C, Di Donna P, *et al*. Long-term follow-up of right ventricular monomorphic extrasystoles. J Am Coll Cardiol 2001; 38: 364-70.
8. Chugh SS, Shen WK, Luria DM, Smith HC. First evidence of premature ventricular complex-induced cardiomyopathy: a potentially reversible cause of heart failure. J Cardiovasc Electrophysiol 2000; 11: 328-9.
9. Hoffman BF, Bartelstone HJ, Scherlag BJ, Cranefield PF. Effects of postextrasystolic potentiation on normal and failing hearts. Bull NY Acad Med 1965; 41: 498-534.
10. Kim RJ, Iwai S, Markowitz SM, Shah BK, Stein KM, Lerman BB. Clinical and electrophysiological spectrum of idiopathic ventricular outflow tract arrhythmias. J Am Coll Cardiol 2007; 49: 2035-43.
11. Wilkoff BL, Cook JR, Epstein AE, *et al*. Dual-chamber pacing or ventricular backup pacing in patients with an implantable defibrillator: the Dual Chamber and VVI Implantable Defibrillator (DAVID) Trial. JAMA 2002; 288: 3115-23.
12. Moulton KP, Medcalf T, Lazzara R. Premature ventricular complex morphology. A marker for left ventricular structure and function. Circulation 1990; 81: 1245-51.
13. Angeles K, Betzu R, Gould LA. Is the morphology of ventricular premature beats a marker for left ventricular dysfunction? N Y State J Med 1992; 92: 89-91.
14. Satish OS, Yeh KH, Wen MS, Wang CC. Premature ventricular contraction-induced concealed mechanical bradycardia and dilated cardiomyopathy. J Cardiovasc Electrophysiol 2005; 16: 88-91.
15. Duffee DF, Shen WK, Smith HC. Suppression of frequent premature ventricular contractions and improvement of left ventricular function in patients with presumed idiopathic dilated cardiomyopathy. Mayo Clin Proc 1998; 73: 430-3.
16. Yarlagadda RK, Iwai S, Stein KM, *et al*. Reversal of cardiomyopathy in patients with repetitive monomorphic ventricular ectopy originating from the right ventricular outflow tract. Circulation 2005; 112: 1092-7.
17. Kanei Y, Friedman M, Ogawa N, Hanon S, Lam P, Schweitzer P. Frequent premature ventricular complexes originating from the right ventricular outflow tract are associated with left ventricular dysfunction. Ann Noninvasive Electrocardiol 2008; 13(1): 81-5.
18. Bogun F, Crawford T, Reich S, *et al*. Radiofrequency ablation of frequent, idiopathic premature ventricular complexes: comparison with a control group without intervention. Heart Rhythm 2007; 4: 863-7.
19. Taieb JM, Maury P, Shah D, *et al*. Reversal of dilated cardiomyopathy by the elimination of frequent left or right premature ventricular contractions. J Interv Card Electrophysiol 2007; 20: 9-13.
20. Baman TS, Lange DC, IIg KJ, *et al*. Relationship between burden of premature ventricular complexes and left ventricular function. Heart Rhythm 2010; 7: 865-9.
21. Niwano S, Wakisaka Y, Niwano H, *et al*. Prognostic significance of frequent premature ventricular contractions originating from the ventricular outflow tract in patients with normal left ventricular function. Heart 2009; 95: 1230-7.
22. Sarrazin JF, Labounty T, Kuhne M, *et al*. Impact of radiofrequency ablation of frequent post-infarction premature ventricular complexes on left ventricular ejection fraction. Heart Rhythm 2009; 6: 1543-9.
23. Lerman BB, Stein KM, Markowitz SM, Mittal S, Iwai S. Ventricular tachycardia in patients with structurally normal hearts. In: Zipes DP, Jalife J. *Cardiac Electrophysiology : From Cell to Bedside*. 4th edition. Philadelphia: Saunders Corp; 2004: 668-82.
24. Nagueh SF, Middleton KJ, Kopelen HA, Zoghbi WA, Quiñones MA. Doppler tissue imaging: a noninvasive technique for evaluation of left ventricular relaxation and estimation of filling pressure. J Am Coll Cardiol 1997; 30: 1527-33.
25. Rossi MA. Pathologic fibrosis and connective tissue matrix in left ventricular hypertrophy due to chronic arterial hypertension in humans. J Hypertension 1998; 16: 1031-41.