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Left ventricular systolic and diastolic function in patients with atrioventricular nodal re-entrant tachycardia treated by radiofrequency current ablation

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Abstract

Background: *The impact of radiofrequency current ablation (RFCA) on left ventricular (LV) systolic and diastolic function in patients with atrioventricular nodal re-entrant tachycardia (AVNRT) is not well established yet.*

Methods: *The study group consisted of 25 patients (18 W, mean age 43 ± 11) with recurrent episodes of AVRT without any concomitant diseases. The control group was formed of 25 healthy volunteers. In both study and control groups, transthoracic echocardiography (TTE) and Doppler were performed in order to assess LV systolic and diastolic function. In AVNRT syndrome patients, TTE was followed by electrophysiology study and RFCA. TTE was repeated after six months in the study group.*

Results: *Significant differences were found between the study and control groups with regard to LV systolic (FS — fractional shortening: 37 ± 4* vs. *42 ± 6%, $p = 0.001$; ESV — end-systolic volume: 19 ± 4* vs. *17 ± 4 ml/m², $p = 0.03$; EF — ejection fraction: 55 ± 5* vs. *62 ± 4%, $p = 0.001$) and diastolic function (E wave: 69 ± 17* vs. *84 ± 15 cm/s, $p = 0.002$; E/A: 1.09 ± ± 0.42* vs. *1.38 ± 0.27, $p = 0.005$; ΔT — duration difference between A and AR waves: 7 ± 29* vs. *–28 ± ± 13 ms, $p = 0.001$; DT — deceleration time of E wave: 223 ± 34* vs. *177 ± 27 ms, $p = 0.001$; IVRT — isovolumic relaxation time: 105 ± 15* vs. *86 ± 11 ms, $p = 0.001$; E/A while Valsalva manoeuvre: 0.93 ± 0.35* vs. *1.25 ± 0.16, $p = 0.001$; AR — atrial reversal velocity: 27 ± 7* vs. *14 ± ± 11 cm/s, $p = 0.001$) variables. In 6-month follow-up decrease in LVESV (19 ± 4* vs. *17 ± ± 4 ml, $p < 0.03$) and increase in EF (55 ± 5* vs. *62 ± 4%, $p < 0.001$) was noted. Doppler analysis showed an increase in E wave (69 ± 17* vs. *79 ± 20 cm/s, $p < 0.02$), E/A ratio (1.09 ± ± 0.42* vs. *1.30 ± 0.27, $p < 0.006$) and decrease in A wave (68 ± 13* vs. *63 ± 10 cm/s, $p < 0.02$), DT (223 ± 34* vs. *179 ± 22 ms, $p < 0.001$), IVRT (105 ± 15* vs. *89 ± 11 ms, $p < 0.001$) and ΔT (7 ± 29* vs. *–13 ± 28 ms, $p < 0.001$).*

Conclusions: *Successful RFCA of slow atrioventricular conduction pathway in patients with AVNRT and AVRT results in improvement of LV systolic and diastolic function.* (Cardiol J 2008; 15: 150–155)

Key words: radiofrequency ablation, re-entrant tachycardia, left ventricular function

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Introduction

Chronic supraventricular tachycardia may result in dilated cardiomyopathy both in animals [1, 2] and humans [3]. In addition, patients with frequent and prolonged episodes of tachycardia are at risk of developing left ventricular (LV) dysfunction. Pharmacological control of heart rate or elimination of tachycardia via current or surgical ablation may reverse LV dysfunction [4, 5]. We sought to determine whether radiofrequency current ablation (RFCA) has an impact on LV systolic and diastolic function in patients with atrioventricular node dissociation and irregular episodes of atrioventricular nodal re-entrant tachycardia (AVNRT).

Methods

From March 1998 to December 2000, 158 consecutive patients with symptomatic drug-resistant tachycardia underwent an invasive electrophysiology study (EPS) and RFCA of slow conduction pathway within atrioventricular node. Having obtained informed consent, transthoracic echocardiography (TTE) followed by EPS and RFCA were performed. Patients were included in the study group if, during EPS presence, atrioventricular node dissociation was confirmed and AVNRT was induced. Patients with Wolf-Parkinson-White syndrome (n = 74), failure to induce AVNRT during EPS (n = 5), concomitant diseases such as coronary artery disease (n = 2), valve disease (n = 17), chronic myocarditis (n = 1), hypertension — defined as systolic blood pressure exceeding 140 mm Hg and/or diastolic blood pressure over 90 mm Hg during high blood pressure or normal blood pressure on antihypertensive drugs (n = 11), metabolic diseases (diabetes mellitus: n = 1, hypothyroidism: n = 1), obesity — defined as body mass index over 30 (n = 7), conduction disturbances (LBBB: n = 1), poor TTE image (n = 8), and patients taking any drugs (n = 5) were excluded from the study.

To define the frequency of AVRT episodes and to reduce the error of precise AVNRT duration based on patient history, the scale of AVRT occurrence (Scale: 3 — at least once a week, 2 — at least once a month, 1 — less than once a month) was introduced.

The study was approved by the local bioethical committee.

Transthoracic echocardiography

Transthorasic echocardiography (TTE) was performed without any information on the patient or clinical data, using an ACUSON 128XP with a 2.5–3.5 MHz transducer. All measurements were made according to established standards [6]. The M-mode traces and Doppler signals were recorded at 50 mm/s. The average of three consecutive cycles was calculated for each parameter. Measurements of LV end-diastolic (EDD), end-systolic (ESD), left atrial (LAD), intraventricular septal (IVS) and LV posterior wall (PW) end-diastolic and end-systolic dimensions were made on M-mode traces recorded from the parasternal long-axis view. LV end-diastolic (EDV) and end-systolic volumes (ESV) were acquired from the apical four-chamber view. LV ejection fraction (EF) by bi-plane Simpson method, LV mass (M) and fractional shortening (FS), IVS and PW thickening (IVSth, PWth) were also calculated. Doppler parameters of mitral and right upper pulmonary vein (RUPV) flow reflecting LV filling were obtained from the apical four-chamber view with a sample volume of 2–4 mm. Mitral flow measurements included peak early transmitral filling velocity during early diastole (E), peak transmitral atrial filling velocity during late diastole (A), deceleration time (DT — time elapsed between peak E velocity and the point where the extrapolation deceleration slope of the E velocity crosses the zero baseline), isovolumic relaxation time (IVRT — time between the aortic valve closure and mitral valve opening) and duration of A wave (tA). Assessment of RUPV flow involved systolic (S), diastolic (D), atrial reversal (AR) peak velocities and duration of AR (tAR) wave measurements. Ratio of E and A (E/A) and S and D (S/D) waves and the difference between the duration of AR and A waves (ΔT) were calculated. Measurements of mitral and RUPV flows allowed the assessment of LV diastolic function [7]: 1) normal, 2) slow isovolumic relaxation [IVRT > 92 ms (< 30 years), IVRT > 100 ms (30–50 years), IVRT > 105 ms (> 50 years)], 3) slow early LV filling [E/A < 1 and DT > 220 ms (< 50 years), E/A < 0.5 and DT > 280 (> 50 years), S/D > 1.5 (< 50 years), S/D < 0.5 (> 50 years)], 4) mitral flow pseudonormalization (E/A > 1, DT and IVRT normal adjusted for age and complying with at least three of the following criteria [8]: S < D, E < A and increase in A velocity during Valsalva manoeuvre, AR ≥ 0.35 m/s, ΔT = tAR-tA ≥ 20 ms), and 5) mitral flow restriction (E/A > 2, DT < 140 ms, S/D < 0.5, AR > 0.35 m/s, ΔT > 30 ms).

Electrophysiology study and ablation procedure

Electrophysiology study (EPS) and RFCA were performed according to the previously described procedure [9]. All antiarrhythmic drugs were

Table 1. Study sample.

Parameter	AVNRT group (n = 25)	Control group (n = 25)	p
Age (years)	42.7 ± 11.3	42.0 ± 9.5	0.80
Gender	7 M (28%)	7 M (28%)	1.0
Body mass index [kg/m^2]	24.1 ± 2.1	23.8 ± 2.2	0.67
Body surface area [m^2]	1.8 ± 0.2	1.7 ± 0.1	0.31
Systolic blood pressure [mm Hg]	123.0 ± 11.1	123.4 ± 11.0	0.90
Diastolic blood pressure [mm Hg]	77.0 ± 7.9	78.2 ± 7.9	0.59

AVNRT — atrioventricular nodal re-entrant tachycardia

discontinued at least three half-lives before the study except from amiodarone which was withdrawn two months before the study. EPS was performed using quadripolar diagnostic electrodes introduced under fluoroscopic guidance. Three of the electrodes with a 0.5-cm interpolar distance were introduced via femoral veins into the right atrial appendage (HRA), His bundle area (HBE) and right ventricle apex (RVA). A fourth quadripolar diagnostic electrode recording uni- and bipolar signals from the coronary sinus (CS) was introduced via the right internal jugular vein. The electrode was positioned in a standard location. The right atrium and right ventricle were paced with impulses generated by Biotronic (Quinton Electrophysiology Corp., Seattle, WA, USA), recorded and displayed with the help of a 1993 Quinton EPAmp electrophysiological monitoring system. Two stimulation protocols were performed during the study: 1) programmed stimulation of the HRA with 8 basic stimuli train and subsequent single, and afterwards double extrastimuli with gradually (20-ms step) shortened coupling interval, and 2) incremental pacing protocol. Radiofrequency catheter ablation was performed with the ablation catheter placed at the site of earliest activation, using commercial ablation electrodes (Daig, Cordis, Medtronic). Radiofrequency energy was delivered at an energy of 40 W and temperature up to 60°C, for 60 s. Stimulation protocols were repeated after ablation RF in order to stimulate AVNRT and to confirm elimination of tachyarrhythmia.

Statistical analysis

All values were expressed as mean ± SD. Differences between study and control groups were evaluated by Student's unpaired test for continuous variables and χ^2 analysis for discreet variables. Analysis of systolic and diastolic function parameters before and after RFCA was performed by Student's paired test for continuous variables. P value < 0.05 was required to fulfil statistical significance. All calculations were performed using a commercially available statistical package SAS 9.1.3 (SAS Institute Inc., Cary, NC).

Reproducibility

All measurements were made by two independent observers and repeated in ten randomly chosen patients at least one month from the baseline TTE, in order to assess intra- and inter-observer variability calculated as the difference of two values and their arithmetical mean quotient. Intra- and inter-observer variability was found as follows: for LV diameters: 1.7 ± 2.9% and 3.3 ± 2.1, LV volumes: 3.5 ± 3.2% and 7.7 ± 2.8, FS: 2.3 ± 2.2% and 4.4 ± 2.6, EF: 4.5 ± 3.1 and 6.3 ± 3.4, mitral and RUPV flow velocities: 2.6 ± 2.8 and 1.3 ± 2.5%, DT and IVRT: 7.1 ± 5.4 and 9.1 ± 4.6%.

Results

In all patients, AVNRT (mean frequency 181 ± ± 16 beats/min, mean scale of occurrence 1.7 ± 0.5) was induced during EPS. The study group characteristics are presented in Table 1. No difference was found between age, gender, body mass index, body surface area and values of systolic and diastolic blood pressure. Ablation RF successfully eliminated tachyarrhythmia in 25 (100%) patients. There were no major complications of the procedure. Minor complications (inguinal bruising) occurred just in one (4%) patient and no major complications. In 6-month follow-up, none of the patients experienced recurrence of AVNRT episodes.

Systolic function

Results of LV systolic parameter comparison between the study and control groups are presented in Table 2. Statistically significant differences in LV fractional shortening, end-systolic volume and ejection fraction were found between AVNRT and control groups. Eleven (44%) patients presented baseline LV ejection fraction below 55% (mean 51 ± 2%).

Table 2. Left ventricular systolic function characteristics of the study sample.

Variable	Before RFCA (n = 25)	Post RFCA	Control group (n = 25)	p*	p**	p***
Heart rate [1/min]	74 ± 9	72 ± 9	71 ± 7	0.22	0.42	0.77
EDD [mm/m²]	27 ± 2	27 ± 3	28 ± 3	0.08	0.91	0.11
ESD [mm/m²]	16 ± 4	16 ± 2	16 ± 2	0.98	0.80	0.76
LAD [mm/m²]	20 ± 25	19 ± 4	20 ± 23	0.64	0.88	0.59
FS (%)	37 ± 4	38 ± 6	42 ± 6	0.001	0.42	0.03
IVSth (%)	46 ± 16	47 ± 13	52 ± 18	0.19	0.80	0.23
PWth (%)	63 ± 18	62 ± 19	60.9 ± 15.4	0.88	0.78	0.88
EDV [ml/m²]	41 ± 7	41 ± 8	43.9 ± 12	0.52	0.81	0.41
ESV [ml/m²]	19 ± 4	15 ± 5	17 ± 4	0.03	0.004	0.37
EF (%)	55 ± 5	62 ± 5	62 ± 4	0.001	0.001	0.72

*p — comparison between AVNRT and control group; **p — comparison between AVNRT before and after radiofrequency current ablation (RFCA); ***p — comparison between AVNRT after RFCA and control group; EDD — LV end-diastolic diameter; ESD — LV end-systolic diameter; LAD — left atrial end-diastolic diameter; M — LV mass; FS — LV fractional shortening; IVSth — intraventricular septal thickening; PWth — posterior wall thickening; EDV — LV end-diastolic volume; ESV — LV end-systolic volume; EF — LV ejection fraction

Successful RFCA resulted in reduction of end-systolic diameter and, in consequence, increase in LV ejection fraction. LV systolic function parameters, apart from LV fractional shortening, did not differ between study and control groups post successful RFCA.

Diastolic function

Comparison of LV diastolic function parameters between study and control groups are shown in Table 3. In five (20%) patients of the study group there were no LV diastolic function abnormalities. However, slow isovolumic relaxation was found in six (24%), slow early LV filling in nine (36%) and mitral flow pseudonormalization in five (20%). Restrictive filling patterns were not seen in any of the AVNRT patients. Diastolic dysfunction was not found in any subject from the control group.

Following successful RFCA in 22 (88%) patients, LV diastolic dysfunction was absent. Slow isovolumic relaxation was found in two (8%) patients and slow early LV filling in one (4%). Mitral flow pseudonormalization or restriction were not present in any of the patients. In 18 (90%) patients with baseline diastolic abnormalities, diastolic function improved post successful RFCA. In two (10%)

Table 3. Left ventricular diastolic function characteristics of the study sample.

Parameter	Before RFCA (n = 65)	Post RFCA	Control group (n = 50)	p*	p**	p***
E [cm/s]	69 ± 17	79 ± 20	84 ± 15	0.002	0.02	0.31
A [cm/s]	68 ± 13	63 ± 10	62 ± 11	0.11	0.02	0.86
E/A	1.09 ± 0.42	1.30 ± 0.27	1.38 ± 0.27	0.005	0.006	0.38
∆T [ms]	7 ± 29	–13 ± 28	–28 ± 13	0.001	0.001	0.02
DT [ms]	223 ± 34	179 ± 22	177 ± 27	0.001	0.001	0.79
IVRT [ms]	105 ± 15	89 ± 11	86 ± 11	0.001	0.001	0.40
Ev [cm/s]	55 ± 16	61 ± 13	69 ± 12	0.001	0.08	0.03
Av [cm/s]	60 ± 13	58 ± 12	56 ± 11	0.20	0.17	0.52
E/Av	0.93 ± 0.35	1.09 ± 0.29	1.25 ± 0.16	0.001	0.04	0.03
S [cm/s]	55 ± 10	56 ± 11	58 ± 8	0.40	0.60	0.27
D [cm/s]	53 ± 13	51 ± 10	56 ± 8	0.27	0.71	0.06
S/D	1.09 ± 0.30	1.13 ± 0.28	1.07 ± 0.20	0.73	0.80	0.37
AR [cm/s]	27 ± 7	22 ± 8	14 ± 11	0.001	0.06	0.006

*p — comparison between AVNRT and control group; **p — comparison between AVNRT before and after radiofrequency current ablation (RFCA); ***p — comparison between AVNRT after RFCA and control group; E — peak early transmitral filling velocity during early diastole; A — peak transmitral atrial filling velocity during late diastole; ∆T — duration difference between RUPV atrial reversal flow and mitral A wave; DT — deceleration time of E wave; IVRT — isovolumic relaxation time; Ev — E wave during Valsalva manoeuvre; Av — A wave during Valsalva manoeuvre, S — systolic velocity of right upper pulmonary vein (RUPV) flow; AR — atrial reversal velocity of RUPV flow patients after RFCA there was no regression of diastolic dysfunction (one patient with slow isovolumic relaxation, one patient with slow early LV filling). Successful RFCA resulted in an increase in early mitral filling, early to atrial mitral flow ratio at rest and during Valsalva manoeuvre and reduction of atrial mitral. Systolic and diastolic velocities of RUPV flow did not change. The majority of LV diastolic function parameters post successful RFCA did not differ between study and control groups. Although reduction of duration difference between RUPV atrial reversal flow and mitral A wave and increase in early transmitral filling velocity, early to atrial transmitral flow ratio while Valsalva manoeuvre increased post RFCA, they did not reach the values observed in healthy subjects.

Discussion

Chronic supraventricular tachycardia may lead to the development of congestive heart failure, which has been well documented both in animal and clinical models [1, 2, 10–12]. We have already shown that recurrent episodes of re-entrant tachycardia may also affect LV systolic and diastolic performance [13]. Several studies have reported improvement of LV systolic function due to elimination of tachycardia by ablation of atrioventricular conduction or AP [14, 15]. However, regression of diastolic dysfunction as a result of tachycardia termination is not clear. Tomita et al. demonstrated that in the 4-week recovery period increase in LV diastolic and pulmonary wedge pressure were still persistent [12].

Systolic function

Reversibility of LV dysfunction was observed by Chen et al. in patients with frequent attacks of prolonged tachycardia and with incessant re-entrant tachycardia post successful direct or radiofrequency catheter ablation [16], by Cruz et al. [5] in patients with permanent junctional reciprocating tachycardia (PJRT) and by De Giovanni et al. [4] in children with PJRT and ectopic atrial tachycardia treated by RFCA, surgical or DC ablation. In our study elimination of the arrhythmia was achieved by RFCA of slow accessory pathways within atrioventricular node. None of the patients underwent surgical ablation, nor was atrioventricular conduction block created in any subject. We observed improvement of LV fractional shortening and ejection fraction post successful RFCA as a result of reduction of LV end-systolic without significant decrease in LV end-diastolic volume. Contrary to other studies [1, 2, 5, 11, 12, 16], our patients did not have LV end-diastolic dilation. This difference may be explained by the fact that not only organic heart disease but also any concomitant diseases or any drug intake were defined as exclusion criteria from the study. Similar findings were reported by Fishberger et al. [17] in patients with ectopic atrial and permanent junctional reciprocating tachycardia.

Diastolic function

We have already proven that recurrent episodes of AVNRT may result in LV diastolic dysfunction [13]. Studies reporting whether RFCA alter LV diastolic performance are limited. Shyu et al. [18] have shown that RFCA in patients with AVRT and AVNRT affect left ventricular filling in short term (48 h) observation. Reduction in early transmitral filling velocity and E/A ratio were attributed to increase in heart rate. However, parameters of transmitral flow are not sufficient to assess LV diastolic function, which was proved by Petrie et al. [19]. Eksik et al. [20] reported deterioration of LV diastolic function due to RFCA in patients with various tachyarrhythmias (AVRT, AVNRT, right ventricular outflow tract tachycardia). They analyzed not only transmitral flow but also Tissue Doppler parameters. The most significant deterioration of LV diastolic function was observed one hour and one day after RFCA, and in one month's time it partially improved. Those changes were explained by thermal injury to myocardium, coagulation necrosis and, as a consequence, fibrosis. In neither of the cited above studies re-entrant tachycardia itself was taken into account as a potential factor of LV diastolic function impairment. Induction of AVRT or AVNRT is part of the EPS study.

Our study has demonstrated that successful RFCA results in improvement of LV diastolic function in 6-month follow-up. Only in two (10%) patients with baseline diastolic abnormalities were slow relaxation and slow early LV filling present post RFCA. This may be explained by the age of the patients (mean 53 ± 12) combined with scale of AVNRT occurrence [2] and frequency of AVNRT (185 ± 7 beats/min). Post RFCA, the majority of transmitral flow parameters improved. Although systolic and diastolic velocities of RUPV flow did not alter significantly after RFCA, reduction in atrial reversal flow was noted. It has to be taken into consideration that there is no linear relation between RUPV flow systolic and diastolic velocities and grades of diastolic dysfunction. Therefore, mean values of those parameters may not differ before and after ablation. The relation between those parameters has been proved in other studies [21].

Reduction of atrial reversal flow post RFCA was insignificant and still different from values observed in healthy subjects. Mele et al. [22] indicate that during AVRT in about 90% of cases atrial contraction occurs against totally (AVNRT) or partially (AVRT) closed atrioventricular valves. This results in repeated mean and peak atrial pressure elevations and may lead to atrial remodelling which could be persistent in long-term follow-up.

Clinical implications

Elimination of AVNRT in patients with atrioventricular node dissociation results in improvement of LV systolic and diastolic performance. Therefore, given the results and the low rate of complications of RFCA [23], such treatment should be considered early in patients with atrioventricular node dissociation and recurrent episodes of AVNRT.

Study limitations

Echocardiographic findings were not verified by invasive mean LA pressure or LVEDP measurements which could bring an additional value to the study. LV diastolic function evaluation was limited to conventional Doppler but not Tissue Doppler or propagation velocity imaging. However, to the best of our knowledge this is the first study providing information on LV diastolic performance in patients with AVNRT undergoing successful RFCA.

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