ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Effect of cardiac resynchronisation therapy on coronary blood flow in patients with non-ischaemic dilated cardiomyopathy

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Abstract

Background: Cardiac resynchronisation therapy (CRT) has beneficial effects on cardiac function, exercise tolerance, symptoms, and prognosis. Coronary blood flow impairment has been observed in patients with non-ischaemic dilated cardiomyopathy (DCM) despite angiographically normal coronary arteries. No data are available on coronary blood flow and coronary flow reserve (CFR) measured by intracoronary Doppler in different coronary arteries in patients with DCM and left bundle branch block (LBBB) before and during treatment with CRT.

Aim: Thus, the major aim of our study was to assess the effect of CRT on coronary blood flow in patients with non-ischaemic DCM and to compare coronary blood flow and CFR measured in the 3 major coronary arteries (left anterior descending [LAD], left circumflex [LCX], and right coronary artery [RCA]).

Methods: Twenty one patients with DCM and LBBB (mean left ventricular ejection fraction 26 ± 7%, 5 females, mean age 57.8 ± 8.1 years) were studied. Average peak velocity, diastolic/systolic velocity ratio and CFR were measured using intracoronary Doppler before and 6–9 months after implantation of CRT-D or CRT-P.

Results: In patients with a clinical improvement (71.4%), CFR increased in LAD. CFR measured in LCX and RCA did not improve either in the overall study group or in patients with a clinical improvement. The observed increase in CFR in LAD correlated only with reduction of QRS duration.

Conclusions: In non-ischaemic DCM, CFR is reduced only in LAD. A significant improvement of CFR in LAD after CRT correlates with reduction of QRS duration.

Key words: cardiac resynchronisation therapy, heart failure, dilated cardiomyopathy, coronary blood flow, coronary flow reserve

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INTRODUCTION

Cardiac resynchronisation therapy (CRT) has a beneficial effect on left ventricular (LV) function, reduces clinical symptoms of heart failure (HF), and reduces mortality [1–4].

Reduction of coronary blood flow and coronary flow reserve (CFR) in patients with HF is associated with worse outcomes [5, 6].

Improvement of LV function with CRT results from improved synchrony of ventricular contraction and improved interventricular mechanical synchrony, which does not have to be associated with improved electrical synchrony, i.e. QRS complex narrowing [7].

A left bundle branch block (LBBB) is often present in patients with non-ischaemic dilated cardiomyopathy (DCM). LBBB itself has a negative effect on coronary perfusion, particularly within the interventricular septum, and reduces duration of coronary flow which may be additionally shortened due to diastolic dysfunction [8, 9].

A larger baseline mean coronary blood flow velocity, as measured by intracoronary Doppler and echocardiography

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in the left anterior descending artery (LAD), and lower CFR was found in patients with LBBB and no evidence of HF or reduced (< 50%) LV ejection fraction (LVEF) compared to patients without LBBB [8, 9]. No similar comparisons were reported for flow in the right coronary artery (RCA) and the left circumflex artery (LCX).

The aim of our study was to evaluate the effect of CRT on coronary blood flow and CFR, and the importance of these for the improvement of cardiac function in patients with DCM. Specifically, we evaluated blood flow parameters including flow reserve in large epicardial arteries (LAD, LCX, and RCA) and correlated them with cardiac function at baseline and at the end of follow-up (clinical, echocardiographic, and electrocardiographic parameters) to determine possible associations between changes in coronary blood flow and CFR parameters resulting from CRT and cardiac functional status.

METHODS

Patients

The study group included 21 patients (5 women, mean age 57.8 ± 8.1 years, median 56 years, range 45–76 years) with HF resulting from DCM and concomitant LBBB who were selected for CRT (CRT-D or CRT-P). All patients had angiographically normal coronary arteries. The patients were prospectively included into the study. The study protocol was accepted by the bioethics committee at the Pomeranian Medical University in Szczecin, Poland. All patients signed a written informed consent for participation in the study.

Coronary blood flow measurements

Immediately after coronary angiography, a Doppler probe (FloWire, Cardiometrics, Inc., Mountain View, CA, USA) was introduced to proximal LAD, the initial part of distal LCX, and the second segment of RCA. We measured average peak velocity (APV) and diastolic/systolic velocity ratio (DSVR) in resting conditions and during hyperaemia after intracoronary administration of adenosine (40 μg to LAD and LCX, 30 μg to RCA) [10]. CFR was calculated automatically as the ratio of APV after adenosine administration to APV in resting conditions. Measurements were performed at baseline (before initiation of CRT) and at 6–9 months (mean 6.7 ± 0.9 months, median 7 months) after CRT-D or CRT-P implantation.

Clinical evaluation of improved cardiac function

Clinical improvement at 6–9 months of CRT was defined as reduction by ≥ 1 functional class in the New York Heart Association (NYHA) classification, and an increase in the 6-min walk test distance by ≥ 20%.

Statistical analysis

Numeric variables were reported as mean values ± standard deviation and as medians and ranges. Continuous variables were compared using the Mann-Whitney U test, and dichotomous variables were compared using the χ^2 test and the Fisher exact test. Intragroup comparisons of blood flow parameters were performed using the analysis of variance (ANOVA) and the Wilcoxon test. P < 0.05 was considered statistically significant.

RESULTS

Clinical characteristics and baseline echocardiographic parameters in the study group are shown in Table 1.

At baseline, we did not find any relations between APV, DSVR and CFR in any of the coronary arteries and parameters of cardiac function and HF (NYHA class, LVEF, LV end-diastolic diameter, mitral regurgitation, 6-min walk test distance) and parameters of cardiac dyssynchrony (QRS duration, septal-to-posterior wall motion delay, difference between pulmonary and aortic flow delay as measured from the beginning of the QRS). Detailed data for LAD are shown in Table 2.

Comparison of blood flow parameters in coronary arteries at baseline (before CRT)

In resting conditions, LAD flow was larger than RCA flow (p = 0.001) and LCX flow (marginal difference at p = 0.051). Peak flow velocity in LCX was significantly higher compared to RCA (p = 0.0005). During hyperaemia, LCX peak flow velocity was significantly higher compared to RCA (p = 0.026), and LAD peak flow velocity was marginally higher compared to RCA (p = 0.091) (Table 3).

In resting conditions, DSVR was significantly higher in LAD compared to LCX (p = 0.027) and insignificantly higher in RCA compared to LCX (p = 0.088). During hyperaemia, DSVR in LCX significantly higher compared to LAD (p = 0.015) and RCA (p = 0.022) (Table 4).

CFR was significantly smaller in LAD compared to LCX and RCA (p = 0.025 and p = 0.016, respectively). Differences in CFR between LCX and RCA were not significant (p = 0.065). Detailed results are shown in Table 5.

Comparison of blood flow parameters in coronary arteries after CRT

At 6–9 (mean 6.9 ± 0.9) months of CRT, comparisons of resting APV between the major coronary arteries yielded results similar to those found at baseline (Table 3). During hyperaemia, peak flow velocity in LAD was higher compared to RCA and marginally higher compared to LCX. Differences between LCX and RCA were not significant (Table 3).

Compared to baseline (before CRT), DSVR measurements in resting conditions showed significant differences between LAD and RCA (a marked increase in DSVR in LAD, p = 0.017). During hyperaemia, DSVR was significantly higher in LAD compared to RCA. Differences between LAD and LCX were not significant, and differences between LCX and RCA were marginally significant (Table 4).

Coronary flow reserve increased in LAD and thus differences between the major coronary arteries became insignificant (Table 5).

Table 1. Clinical characteristics and baseline echocardiographic parameters in the study group

	Overall (n = 21)	Responders (n = 15)	Non-responders (n = 6)	P (responders vs. non-responders)
Age [years]	57.8 ± 8.1; 56; 45–76	58 ± 8; 56; 45–76	56 ± 9; 55; 47–69	0.25
Men	75%	73%	83%	0.31
Atrial fibrillation	4.8%	0%	17%	0.0001
Diabetes	24%	20%	33%	0.05
Hypertension	29	33	17	0.05
NYHA class	3.0 ± 0.4; 3; 2–3.5	3.1 ± 0.2; 3; 3–3.5	2.7 ± 0.5; 3; 2–3	0.04
LVEF [%]	26 ± 7; 25; 15–35	25 ± 7; 25; 15–35	28 ± 7; 30; 15–35	0.04
LVEDD [mm]	71 ± 8; 70; 58–87	73 ± 9; 74; 58–87	67 ± 2; 66.5; 63–69	0.03
SPWMD [ms]	118 ± 29; 120; 60–180	113 ± 32; 116; 60–180	132 ± 16; 125; 118–155	0.03
QPul-QAo [ms]	59 ± 23; 55; 30–109	61 ± 26; 55; 30–109	55 ± 15; 57; 32–74	0.06
MR (graded 0–4)	2.6 ± 0.8; 2.5; 1–4	2.8 ± 0.7; 3; 1–4	2.1 ± 0.6; 2.3; 1–3	0.02
Left bundle branch block (n)	21	15	6	
QRS duration [ms]	153 ± 17; 150; 120–180	154 ± 19; 150; 120–180	150 ± 14; 150; 130–170	0.14
Six-min walk test distance [m]	300 ± 99; 300; 140–425	307 ± 72; 300; 220–475	283 ± 121; 275; 140–450	0.10
Medications:				
Diuretic	75%	87%	50%	0.06
ACE inhibitor	95%	100%	83%	0.06
Beta-blocker	71%	73%	67%	0.10
Digoxin	9.5%	7%	17%	0.15
Amiodarone	9.5%	7%	17%	0.15

Continuous variables are expressed as mean ± standard deviation; median; range. Responders were defined as patients with a clinical improvement following cardiac resynchronisation therapy (CRT), and non-responders as patients with no clinical improvement following CRT; NYHA — New York Heart Association; LVEF — left ventricular ejection fraction; LVEDD — left ventricular end-diastolic diameter; SPWMD — septal-to-posterior wall motion delay; QPul-QAo — difference between pulmonary and aortic flow delay as measured from the beginning of the QRS; MR — mitral regurgitation; ACE — angiotensin-converting enzyme

Table 2. Correlations between average peak velocity (APV), diastolic/systolic velocity ratio (DSVR), and coronary flow reserve (CFR) in the left anterior descending artery and parameters of cardiac functional status and cardiac dyssynchrony at baseline

	Correlation coefficient (R)		
	APV	DSVR	CFR
NYHA	–0.160	–0.130	0.222
LVEF	0.136	–0.140	0.058
LVEDD	–0.075	0.159	–0.186
SPWMD	–0.164	0.007	0.211
QPul-QAo	0.026	–0.137	–0.002
MR (graded 0–4)	0.117	–0.053	–0.0002
QRS duration	–0.145	0.049	–0.047
Six-min walk test distance	0.099	0.014	–0.037

Abbreviations — see Table 1

Comparison of coronary blood flow parameters before and after CRT

Clinical improvement following CRT was noted in 15 of 21 patients (responders, 71.4%). In the overall study group, NYHA class was reduced to mean 2.3 ± 0.4. Among 15 responders, NYHA class was 2.1 ± 0.2 compared to 2.6 ± 0.5 among the remaining 6 non-responders. The 6-min walk test distance increased to 377 ± 62 m among 15 responders, and did not change significantly among the remaining patients (303 ± 125 m).

Table 3. Average peak velocity (APV) in resting conditions and after intracoronary adenosine administration (hyperaemia) at baseline and following cardiac resynchronisation therapy (CRT) in the overall study group

	APV [cm/s]				P	
	Baseline		CRT		Baseline vs. CRT	Baseline vs. CRT
	Resting	Adenosine	Resting	Adenosine	Resting	Adenosine
LAD	20.3 ± 5.4	46.2 ± 10.0	21.3 ± 4.2	55.9 ± 9.0	NS	0.001
LCX	18.6 ± 3.5	47.4 ± 6.5	18.9 ± 3.2	51.3 ± 8.5	NS	0.055
RCA	14.4 ± 3.6	41.7 ± 11.4	15.4 ± 2.4	45.2 ± 8.7	NS	0.06
LAD vs. LCX	0.051	NS	0.045	0.065		
LAD vs. RCA	0.001	0.091	0.001	0.042		
LCX vs. RCA	0.0005	0.026	0.001	NS		

Values are expressed as mean ± standard deviation; LAD — left anterior descending; LCX — left circumflex; RCA — right coronary artery

Table 4. Diastolic/systolic velocity ratio (DSVR) in resting conditions and after intracoronary adenosine administration at baseline and following cardiac resynchronisation therapy (CRT) in the overall study group

	DSVR				P	
	Baseline		CRT		Baseline vs. CRT	Baseline vs. CRT
	Resting	Adenosine	Resting	Adenosine	Resting	Adenosine
LAD	1.06 ± 0.17	1.00 ± 0.15	1.27 ± 0.25	1.22 ± 0.21	0.045	0.038
LCX	0.93 ± 0.13	1.14 ± 0.21	1.05 ± 0.14	1.17 ± 0.22	0.08	NS
RCA	0.99 ± 0.11	1.02 ± 0.10	1.01 ± 0.12	1.04 ± 0.12	NS	NS
LAD vs. LCX	0.027	0.015	0.021	NS		
LAD vs. RCA	NS	NS	0.017	0.045		
LCX vs. RCA	0.088	0.022	NS	0.058		

Values are expressed as mean ± standard deviation; abbreviations — see Table 3

Table 5. Coronary flow reserve (CFR) at baseline and following cardiac resynchronisation therapy (CRT) in the overall study group

		CFR		P
		Baseline	CRT	Baseline vs. CRT
LAD		2.39 ± 0.47; 2.4; 1.7–3.2	2.61 ± 0.49; 2.6; 1.8–3.0	0.055
LCX		2.64 ± 0.35; 2.6; 2.1–3.6	2.71 ± 0.45; 2.7; 2.2–3.7	NS
RCA		2.97 ± 0.81; 3.0; 1.4–4.4	2.95 ± 0.67; 3.0; 1.5–4.1	NS
P	LAD vs. LCX	0.025	NS	
	LAD vs. RCA	0.016	0.056	
	LCX vs. RCA	0.065	NS	

Values are expressed as mean ± standard deviation; median; range; abbreviations — see Table 3

In the overall study group, APV in resting conditions did not increase significantly following CRT in any of the coronary arteries, and during hyperaemia it increased significantly in LAD and insignificantly in LCX and RCA (Table 3). Table 6 shows APV during hyperaemia at baseline and following CRT in the responder and non-responder subgroups. Significant differences between subgroups were found at baseline in all coronary arteries, and following CRT in LAD only. In addition, CRT resulted in a significant increase in CFR in all coronary arteries in the non-responder group, and in LAD only in the responder group.

The DSVR increased significantly only in LAD both at baseline and during hyperaemia (Table 4).

In the overall study group, CFR in LAD increased from 2.39 ± 0.47 to 2.61 ± 0.49 but this difference was not significant ($p = 0.055$).

However, CFR in LAD increased significantly to 2.85 ± 0.62 ($p = 0.045$) among 15 responders. CFR in LCX and RCA did

Table 6. Average peak velocity (APV) after intracoronary adenosine administration (hyperaemia) at baseline and following cardiac resynchronisation therapy (CRT) in the responder and non-responder groups

	Responders			Non-responders			Responders vs. non-responders at baseline	Responders vs. non-responders after CRT
	Baseline	CRT	P	Baseline	CRT	P	P	P
LAD	48.0 ± 10.7	57.8 ± 9.7	0.002	41.8 ± 6.7	49.8 ± 8.6	0.003	0.05	0.045
LCX	49.2 ± 6.1	50.8 ± 6.9	NS	42.8 ± 5.3	51.8 ± 5.9	0.004	0.04	NS
RCA	43.2 ± 12.9	45.4 ± 7.9	NS	38.0 ± 5.2	44.9 ± 6.7	0.002	0.05	NS
LAD vs. LCX	NS	0.01		NS	NS			
LAD vs. RCA	0.02	0.005		NS	0.055			
LCX vs. RCA	0.01	0.045		NS	0.05			

Values are expressed as mean ± standard deviation; abbreviations — see Table 3

Table 7. Coronary flow reserve (CFR) at baseline and following cardiac resynchronisation therapy (CRT) in the responder and non-responder groups

	Responders			Non-responders			Responders vs. non-responders at baseline	Responders vs. non-responders after CRT
	Baseline	CRT	P	Baseline	CRT	P	P	P
LAD	2.33 ± 0.49	2.85 ± 0.62	0.045	2.53 ± 0.44	2.39 ± 0.53	NS	0.067	0.048
LCX	2.58 ± 0.31	2.69 ± 0.42	NS	2.79 ± 0.44	2.75 ± 0.48	NS	0.064	NS
RCA	3.01 ± 0.83	2.96 ± 0.81	NS	2.87 ± 0.82	2.91 ± 0.68	NS	NS	NS
LAD vs. LCX	0.020	NS		0.05	0.017			
LAD vs. RCA	0.013	NS		0.043	0.027			
LCX vs. RCA	0.055	0.068		NS	0.071			

Values are expressed as mean ± standard deviation; abbreviations — see Table 3

not change significantly in the overall study group and among responders and non-responders. Detailed results of CFR measurements in the responder and non-responder groups are shown in Table 7. The observed improvement of CRF in LAD correlated only with reduction of QRS duration following CRT (R = 0.36, p = 0.05). No other studied clinical or echocardiographic parameter showed a significant correlation with CFR increase in LAD.

DISCUSSION

According to our knowledge, it is the first study that evaluated coronary blood flow and CFR in all three major coronary arteries using intracoronary Doppler in patients with DCM before and after CRT.

Major findings

Our study shows that in patients with severe HF (mean LVEF 26 ± 7%) due to DCM (with concomitant LBBB) who showed a clinical improvement after CRT, CFR increased significantly in LAD. CFR in LCX and RCA did not improve either in the overall study group or among responders. CFR increase in LAD correlated only with reduction of QRS duration following CRT (R = 0.36, p = 0.05). In addition, no relations were found at baseline between APV, DSVR and CFR in the major epicardial coronary arteries and the parameters of cardiac functional status and cardiac dyssynchrony.

Comparison with previous studies

The lower limit of CFR measured using various methods in healthy subjects has been defined as 3.0 [11, 12]. Reduced CFR was found in diseases associated with impaired coronary microcirculation despite normal epicardial coronary arteries such as dilated cardiomyopathy (1.9 ± 0.2), hypertrophic cardiomyopathy (2.21 ± 0.2), and cardiac syndrome X (2.27 ± 0.3) [6, 13]. In our study, CFR in LAD was higher compared to other studies. For example, Rigo et al. [14] reported mean CFR in LAD of 2.0 ± 0.5, and most patients (64%) had CFR < 2.0 which was considered an independent predictor of poor outcomes [6]. In our study group, CFR was < 2.0 in only 14% of patients with DCM. CFR in LCX and RCA did not differ from values obtained in these arteries in our previous study in healthy subjects [15]. Of note, CFR did not differ between the three major coronary arteries in subjects without HF (and no LBBB) [8, 15].

Limited and inconsistent data are available regarding the effect of CRT on coronary blood flow and CFR [2, 10–13, 16–18]. Some studies reported no effect of CRT on resting global blood flow despite improved LV function [10, 11, 18–20]. Other studies showed an improvement of inhomogeneous regional flow distribution with CRT [10, 18, 21].

Flevari et al. [13] reported that CRT did not improve resting blood flow and CFR but improved flow during hyperaemia (induced by dipyridamole). However, that study also included patients with coronary artery disease (44%), and measurements were performed by transoesophageal echocardiography (TEE) under sedation with midazolam. In contrast, Valzania et al. [17] showed an increase in coronary blood flow (in LAD, measurements by TEE without sedation) with CRT in patients with DCM which correlated with an improvement of regional contractility and reduction of intraventricular dyssynchrony.

In an acute haemodynamic experiment, Nelson et al. [2] found no difference in CFR (left main coronary artery and proximal LAD) before and during CRT. The study was performed under sedation, and the site of temporary LV pacing was different than during permanent CRT. In addition, CRT improved LV systolic function without a significant increase in oxygen consumption [2].

Our study showed reduced CFR in LAD compared to LCX and RCA. A question arises whether this was due to intraventricular dyssynchrony. All our patients had LBBB which is an electrocardiographic indicator of intraventricular dyssynchrony. In patients who responded to CRT, CFR in LAD improved significantly, which correlated only with reduction of QRS duration, although we found no significant relationship between reduced CFR in LAD and baseline QRS duration.

No studies on the relation between intraventricular dyssynchrony and distribution of coronary flow evaluated using intracoronary Doppler are available in the literature but 1 study reported that in patients with DCM and LBBB, the highest regional oxygen consumption and coronary flow (measured using positron emission tomography [PET]) was found within the lateral wall, and the lowest flow was found within the interventricular septum. No such differences were found in patients with DCM without LBBB [22].

In contrast, studies using thallium-201 and technetium-99m scintigraphy showed that with LBBB, perfusion of the interventricular septum was impaired without lesions in the coronary arteries [23, 24]. RCA and LCX flow was not measured in any of these studies. In experimental animal studies, LBBB induced by ablation resulted in hypoperfusion of the interventricular septum, and led to adverse left ventricular remodelling in the long term [25, 26]. In a small group (n = 8) of patients with DCM and LBBB, Neri et al. [16] showed normal resting blood flow but impaired glucose metabolism within the interventricular septum as measured by PET. CRT only improved glucose metabolism in this area.

In most studies, coronary blood flow was evaluated using TEE, transthoracic echocardiography or PET. Doppler echocardiography (TEE) may only assess LAD flow which correlates well with intracoronary measurements [27]. RCA and LCX are unavailable for this method.

Limitations of the study

The number of patients with DCM in the present study was relatively small, which was related to a complex invasive protocol of the study. We did not compare DCM patients with or without LBBB, as we intended to evaluate patients selected for CRT.

CONCLUSIONS

In non-ischaemic DCM with LBBB, CFR in LAD was significantly lower than in LCX and RCA. A significant improvement of CFR in LAD following CRT correlated only with reduction of QRS duration.

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Conflict of interest: *none declared*

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Wpływ dwukomorowej stymulacji resynchronizującej na wieńcowy przepływ krwi u pacjentów z kardiomiopatią rozstrzeniową niewieńcową

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Streszczenie

Wstęp: Stymulacja resynchronizująca (CRT) korzystnie wpływa na funkcję lewej komory, zmniejsza objawy kliniczne niewydolności serca (HF), poprawia wydolność fizyczną, a także zmniejsza śmiertelność. Redukcja przepływu wieńcowego i jego rezerwy (CFR), która występuje u pacjentów z HF w przebiegu kardiomiopatii rozstrzeniowej, wiąże się z gorszym rokowaniem. U osób z kardiomiopatią rozstrzeniową niewieńcową (DCM) często stwierdza się obecność bloku lewej odnogi pęczka Hisa (LBBB). Już sam LBBB niekorzystnie wpływa na funkcję lewej komory, perfuzję wieńcową, szczególnie w zakresie przegrody międzykomorowej.

Cel: Celem badania była ocena wpływu stymulacji resynchronizującej na wieńcowy przepływ krwi i rezerwę przepływu oraz ich znaczenie dla poprawy wydolności serca u pacjentów z DCM.

Metody: Zbadano 21 pacjentów (5 kobiet, średni wiek 57,8 ± 8,1 roku) z HF (średnia frakcja wyrzutowa = 26 ± 7%) na tle DCM z LBBB zakwalifikowanych do CRT. Wszyscy mieli angiograficznie prawidłowe naczynia wieńcowe. Pomiary przepływu krwi i CFR wykonano techniką wewnątrzwieńcowego doplera w 3 tętnicach wieńcowych wyjściowo i średnio 6,7 miesiąca po zastosowaniu CRT.

Wyniki: U pacjentów, u których zaobserwowano poprawę kliniczną po zastosowaniu resynchronizacji, CFR wzrosła istotnie w zakresie gałęzi przedniej zstępującej lewej tętnicy wieńcowej (LAD). CFR dla gałęzi okalającej lewej tętnicy wieńcowej (LCX) i prawej tętnicy wieńcowej (RCA) nie poprawiła się ani w całej grupie, ani w grupie pacjentów z poprawą kliniczną. Poprawa w zakresie CRF dla LAD koreluje jedynie ze zwężeniem zespołu QRS. Ponadto wyjściowo nie stwierdzono zależności między parametrami przepływu krwi i CFR w dużych tętnicach nasierdziowych a stanem wydolności serca oraz parametrami dyssynchronii (szerokością zespołu QRS, parametrami echokardiograficznymi).

Wnioski: W DCM rezerwa przepływu wieńcowego w LAD była znamiennie mniejsza niż w LCX i RCA. Istotna poprawa CFR w LAD w wyniku zastosowania CRT koreluje jedynie ze zwężeniem zespołu QRS.

Słowa kluczowe: terapia resynchronizująca, niewydolność serca, kardiomiopatia rozstrzeniowa, wieńcowy przepływ krwi, rezerwa przepływu wieńcowego

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