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Relationship between echocardiographic parameters and exercise test duration in patients after myocardial infarction

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Abstract

Background: *The interdependence between echocardiographic parameters of left ventricle function, severity of heart failure (HF) and exercise test duration has not been thoroughly examined.*

Methods: *We compared echocardiographic data in patients after myocardial infarction divided according to NYHA class to mild (class I and II, group 1 = 24 subjects) and advanced HF group (III and IV, group 2 = 36) and assessed their correlation with exercise duration (ED) in a symptom-limited treadmill test. Then we tried to determine independent predictors of ED.*

Results: *The group with advanced HF had lower left ventricle ejection fraction, shorter duration and deceleration times of both mitral inflow waves (Et and At, Edt and Adt) and higher E/A ratio (1.4 ± 1.1* vs. *0.9 ± 0.4; $p < 0.05$) with more frequent restriction and pseudonormalization pattern (56% vs. 12%). Also early wave propagation (21 ± 7 vs. 29 ± 11 cm/s; $p < 0.001$) and all tissue Doppler velocities were lower, but ratio of early wave peak velocity to early diastolic velocity of mitral annulus was higher (E/E' 10.5 ± 5* vs. *6.1 ± 1.3 for velocity ratio; $p < 0.001$) in subjects with more severe clinical symptoms. Significant negative correlation with ED was observed for difference between duration of pulmonary vein atrial reversal flow and atrial wave of mitral inflow (ΔAt; $r = –0.54$) and for E/E' ratio ($r = –0.48$), the highest positive correlation for left ventricular ejection fraction and duration of mitral inflow atrial phase (EF; $r = 0.48$, At; $r = 0.46$). In multivariate stepwise regression analysis two independent predictors of ED were identified: age and ΔAt (Art–At).*

Conclusions: *Diastolic parameters showing the strongest correlation with ED (ΔAt and E/E') are connected with restrictive left ventricle physiology. The only independent predictors of exercise duration in patients after myocardial infarction were: age and ΔAt.* (Cardiol J 2009; 16, 6: 507–513)

Key words: echocardiography, diastolic dysfunction, exercise test duration, heart failure

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Introduction

Although transthoracic echocardiography plays an integral role in the examination of patients with heart failure (HF), the exact correlation between parameters of left ventricle systolic and diastolic function, severity of HF symptoms and exercise test duration is not thoroughly examined. Myocardial damage caused by infarction leads to impairment of both contractility and filling. Despite enlarged heart chambers and low ejection fraction being well-documented predictors of HF development and a poor prognosis, some diastolic measurements may be more precise in diagnostic and prognostic stratification and may show a stronger correlation with exercise tolerance [1–3].

The recently postulated correlation of novel Doppler parameters with end-diastolic left ventricular or pulmonary capillary wedge pressure reinforces the clinical importance of new diastolic variables. These parameters include the velocity and duration of pulmonary vein flow during atrial contraction, the ratio of peak mitral inflow velocity in early phase to early diastolic velocity of mitral annulus (E/E') and ratio of peak mitral inflow velocity in early phase to propagation velocity (E/Ep) [4–6].

The aim of our study was to compare a wide spectrum of echocardiographic parameters between patients after myocardial infarction (MI) presenting with mild (NYHA class I and II) and advanced HF (NYHA III and IV) and to assess the correlation between echocardiographic characteristics of systolic and diastolic function and maximal duration of exercise expressed as time of exercise test and number of MET achieved during symptom-limited exercise test. We also tried to find echocardiographic predictors of exercise duration using a stepwise multivariate model.

Methods

Study group

Our study included 60 consecutive persons with a history of MI (at least six days after occurrence of acute MI) hospitalized in our department who gave informed consent (44 male, mean age 60 ± 11; mean left ventricular ejection fraction 34 ± 11%). All subjects were in sinus rhythm and had no significant valve disease (except for mild mitral insufficiency). Twenty eight patients had a history of percutaneous revascularisation and three of previous coronary artery bypass grafting. Fifty five patients received acetylic salicylic acid, 54 beta-blockers, 48 statins and inhibitors of angiotensin converting enzyme, 44 diuretics, seven digoxin and five oral anticoagulants. Bearing in mind medical history and physical examination, patients were assessed as to their NYHA class and divided into two groups, those with mild HF symptoms (group 1: NYHA I and II, 24 patients) and those with pronounced symptoms (group 2: NYHA III and IV, 36 patients). The mean age of each group was similar (57 ± 10 and 62 ± 12 respectively) but the resting heart rate was significantly higher in group 2 (68 ± 7 *vs*. 77 ± 14).

Demographic and clinical characteristics and comparisons between the group with mild HF and the group with more advanced HF are summarized in Table 1.

Patients without contraindications for exercise (excluding four patients in NYHA class IV) were given the treadmill test according to the Bruce protocol (treadmill Marquete 16). For 46 patients, the test recorded only heart failure symptoms (dyspnea and fatigue). In another ten, chest pain was also recorded. Correlation between echocardiographic parameters and exercise duration was analysed across the whole group of 60 patients (assuming exercise time for patients in NYHA IV class to be zero seconds). Exercise tolerance was expressed as maximal number of MET achieved during the treadmill test.

Echocardiographic assessment

Transthoracic echocardiography was performed with Acuson Sequoia using 3V2 probe. The protocol included calculation of left ventricular ejection fraction by the biplane Simpson method, assessment of mitral inflow pattern (in apical four chamber view with the pulse Doppler sample volume at the tips of opened mitral valve leaflets), pulsed tissue Doppler analysis of mitral annular motion and propagation velocity measurements. Wall thickness and chamber dimensions were measured from two-dimensional (2D) imaging in parasternal long axis view. Isovolumic relaxation time was measured from continuous Doppler recording obtained in apical five chamber view simultaneously displaying aortic ejection and mitral inflow. Isovolumic relaxation time measurement started at the end of aortic ejection (simultaneous with aortic valve closure) and stopped at the beginning of mitral inflow (simultaneous with mitral valve opening).

Propagation velocity for both waves of mitral inflow was measured in colour-M-mode from apical four-chamber view. Sample volume of pulsed tissue Doppler was placed in six points of mitral annulus (adjacent to the posterior and anterior part

Table 1. Demographic and clinical characteristics of patients after myocardial infarction (MI) and comparison between the group with mild, and the group with advanced, heart failure.

Parameter	MI patients	NYHA I–II (G1)	NYHA II–III (G2)	p
Number	60	24	36	–
Age	60 ± 11	57 ± 10	62 ± 12	NS
Male	44 (73%)	15 (63%)	29 (81%)	NS
Hypertension	35 (58%)	15 (63%)	20 (56%)	NS
Diabetes	10 (17%)	5 (21%)	5 (14%)	NS
Hypercholesterolemia	40 (67%)	18 (75%)	22 (61%)	NS
Smoking	29 (48%)	15 (63%)	14 (39%)	NS
Obesity (BMI > 30)	17 (28%)	8 (33%)	9 (25%)	NS
Family history	16 (27%)	6 (25%)	10 (28%)	NS
Heart rate	73 ± 12	68 ± 7	77 ± 14	< 0.01
Anterior wall and septum	44 (73%)	11 (46%)	33 (92%)	NS
Lateral wall	27 (45%)	9 (38%)	18 (50%)	NS
Inferior wall	24 (40%)	11 (46%)	13 (36%)	NS

BMI — body mass index; NYHA — New York Heart Association

of septum, anterior, lateral, posterior and inferior free wall) and spectra of tissue velocities were recorded. We measured peak velocities for systolic, early diastolic and atrial phase of mitral annulus motion in six locations and the average value from all six points was calculated.

Following recommendations published by Oh et al. [7] we accepted E/A ratio < 1 as an indicator of delayed relaxation profile, E/A > 2 as typical for restriction and values of E/A between 1 and 2 as either normal or pseudonormal pattern. Since deceleration time of early wave (Edt) shows a strong inverse correlation with left ventricular filling pressure, well documented in patients with systolic dysfunction, we used the deceleration time below 150 ms as a simplified criterion of pseudonormalization. Pseudonormal pattern was also recognised in patients with prolonged difference between duration of atrial reversal flow in pulmonary vein and mitral flow in atrial phase, delta At ≥ 20 ms (according to Canadian Cardiovascular Society consensus) [8].

The study was approved by the local bioethical committee and all patients gave their informed consent.

Statistical analysis

Statistical analysis was performed using MedCalc V. 6.14. (Frank Schoonjans, Belgium). Continuous variables were expressed as means and standard deviations and means were compared with *t*-Student test for unpaired variables. χ^2 test was used to test the dichotomous variables distribution. Correlation coefficient was calculated from Pearson linear regression model. A p value < 0.05 was considered significant. To find independent predictors of exercise duration, stepwise multivariate regression analysis was performed.

Reproducibility of measurements (interobserver and intraobserver reproducibility of pulsed wave Doppler, tissue Doppler and propagation parameters) was assessed in ten randomly chosen patients as a coefficient of variance from two sets of measurements done by two observers. Coefficient of variability was calculated as the ratio of standard deviation of differences and mean value of measurements.

Results

In the group with advanced HF, left ventricle dimensions were significantly higher (57 ± 9 *vs*. 49 ± ± 7 for diastolic; p < 0.001 and 48 ± 11 *vs*. 39 ± 8 mm for systolic dimension; p = 0.001), Left ventricular ejection fraction was lower (28 ± 8 *vs*. 42 ± 9%) and left atrium larger (46 ± 5 *vs*. 42 ± 6 mm; p = 0.007) than in group 1. Among diastolic parameters in patients with NYHA III and IV class duration and deceleration times of early and atrial mitral inflow waves were shorter. E/A ratio was higher in the advanced HF group (1.4 ± 1.1 *vs*. 0.9 ± 0.4; p < 0.05) with restriction and pseudonormalization of mitral inflow more frequent in this group (56% *vs*. 12%). A comparison of 2D and mitral inflow parameters can be seen in Table 2.

Among pulmonary vein parameters in group 2, maximal velocity of systolic pulmonary vein flow

Table 2. Comparison of 2D echocardiographic and mitral inflow parameters between groups with mild and with advanced, heart failure.

Parameter	NYHA I–II (G1 = 24)	NYHA III–IV (G2 = 36)	p
Profiles N i DR	21	16	0.002
Profiles PN i R	3	20	0.002
LVd [mm]	49 ± 7	57 ± 9	< 0.001
LVs [mm]	39 ± 8	48 ± 11	0.001
LA [mm]	42 ± 6	46 ± 5	0.007
RV [mm]	25 ± 2	25 ± 4	–
LVEF (%)	42 ± 9	28 ± 8	< 0.001
IVRT [ms]	123 ± 21	110 ± 37	NS
E [cm/s]	58 ± 15	69 ± 26	NS
A [cm/s]	69 ± 16	64 ± 24	NS
Et [ms]	297 ± 62	230 ± 76	< 0.001
At [ms]	202 ± 36	146 ± 32	< 0.001
E/A	0.9 ± 0.4	1.4 ± 1.1	0.04
Edt [ms]	211 ± 66	159 ± 63	0.003
Adt [ms]	136 ± 39	89 ± 21	< 0.001

*p < 0.05; mitral inflow profile: N — normal; DR — delayed relaxation; PN — pseudonormal; R — restrictive; LVd — left ventricular diastolic dimension; LVs — left ventricular systolic dimension; LA — left atrium dimension; RV — right ventricle dimension; LVEF — left ventricle ejection fraction; IVRT— isovolumetric relaxation time; E or A, t, dt — early or atrial mitral inflow velocity time or deceleration time

Table 3. Comparison of pulmonary vein flow and propagation parameters between the group with mild, and the group with advanced, heart failure.

Parameter	NYHA I–II (G1 = 24)	NYHA III–IV (G2 = 36)	p
S [cm/s]	54 ± 12	44 ± 14	0.006
D [cm/s]	43 ± 12	49 ± 17	NS
S/D	1.3 ± 0.3	1.1 ± 0.7	NS
Art [ms]	138 ± 22	176 ± 29	< 0.001
Arv [cm/s]	31 ± 6	35 ± 6	0.01
ΔAt (Art–At) [ms]	–64 ± 42	30 ± 42	< 0.001
Ep [cm/s]	29 ± 11	21 ± 7	0.001
Ap [cm/s]	43 ± 13	36 ± 13	NS
E/Ep	2.2 ± 0.9	3.5 ± 1.5	< 0.001

S or D — systolic or diastolic phase of pulmonary vein flow; Art — duration of atrial reversal flow (in pulmonary vein); Arv — peak velocity of atrial reversal; Ep or Ap — early or atrial propagation velocity

Table 4. Comparison of tissue Doppler variables between the group with mild, and the group with advanced, heart failure.

Parameter	NYHA I–II (G1 = 24)	NYHA III–IV (G2 = 34)	p
E' avr [cm/s]	9.7 ± 2.5	7.2 ± 2.3	< 0.001
E' lat [cm/s]	11.4 ± 4.2	8.7 ± 3.6	0.01
A' avr [cm/s]	12.6 ± 3.0	9.3 ± 2.9	< 0.001
A' lat [cm/s]	14.9 ± 4.7	10.2 ± 4.1	< 0.001
S' avr [cm/s]	9.2 ± 2.2	7.5 ± 2.6	0.01
S' lat [cm/s]	10.8 ± 3.9	8.2 ± 3.5	0.009
E/E' avr	6.1 ± 1.3	10.5 ± 5.0	< 0.001
E/E' lat	5.6 ± 1.9	9.1 ± 4.6	< 0.001

E' — early diastolic m.a. velocity; A' — atrial (late diastolic) m.a. velocity; S' — systolic m.a. velocity; E/E'— ratio of peak velocity of mitral inflow early phase to peak velocity of early mitral annulus motion; avr — average value from six point of mitral annulus; lat — parameters measured from lateral part of mitral annulus

was lower and atrial reversal flow velocity was higher than in patients with mild HF (44 ± 14 *vs.* 54 ± ± 12 cm/s and 35 ± 6 *vs.* 31 ± 6 cm/s respectively; p < 0.05). Significantly longer were atrial reversal duration and the difference between atrial reversal duration and time of mitral inflow atrial phase (176 ± ± 29 ms *vs.* 138 ± 22 ms and 30 ± 42 *vs.* –64 ± 42 ms; p < 0.001). Among new diastolic parameters, early wave propagation velocity was lower and ratio of early wave peak velocity to propagation velocity was higher in patients with advanced HF (21 ± 7 *vs.* 29 ± 11 cm/s; p < 0.001 and 3.5 ± 1.5 *vs.* 2.2 ± ± 0.9; p < 0.01). Respective values are compared in Table 3.

All tissue Doppler velocities were lower and ratio of early wave peak velocity to early diastolic velocity of mitral annulus was higher in group 2 (7.2 ± ± 2.3 *vs.* 9.7 ± 2.5 cm/s for early diastolic velocity, 9.3 ± 2.9 *vs.* 12.6 ± 3 cm/s for atrial; p < 0.001 and 7.5 ± 2.6 *vs.* 9.2 ± 2.2 cm/s; p < 0.05 for systolic velocity and 10.5 ± 5 *vs.* 6.1 ± 1.3 for velocity ratio; p < 0.001). This relationship was observed both for measurements averaged from six points of mitral annulus and for parameters measured in lateral part of mitral annulus. Tissue Doppler variables are compared in Table 4.

Exercise duration and tolerance were higher in patients in group 1 (maximal exercise test duration 314 ± 145 *vs.* 100 ± 113 s; p < 0.001) achieved mean MET number 6.1 ± 2.4 *vs.* 2.6 ± 1.9; p < 0.001). Correlation analysis between echocardiographic parameters and exercise duration showed the strongest negative relationship for difference between duration of reversal flow in pulmonary vein and atrial phase of mitral inflow [ΔAt (Art–At); correlation coefficient r = –0.54], and for the ratio of peak early wave velocity of mitral inflow to peak early diastolic velocity of mitral annulus (E/E' avr; r = –0.48, E/E' lat; r = –0.46). The strongest positive interdependence with exercise

Table 5. Correlations of age, ejection fraction, classic and tissue Doppler parameters with exercise duration (ED — duration of symptom--limited treadmill test [ms]) in patients after myocardial infarction (n = 60).

Parameters	r	p
Age	–0.37	0.0035
LA	–0.34	0.0073
LVEF (%)	0.48	0.0001
E [cm/s]	–0.32	0.01
Et [ms]	0.35	0.0063
At [ms]	0.46	0.0002
Adt [ms]	0.35	0.0067
Art [ms]	–0.43	0.0007
Arv [cm/s]	–0.33	0.01
ΔAt (Art–At)	–0.54	< 0.0001
E/Ep	–0.37	0.0034
E' avr	0.42	0.0008
A' avr	0.38	0.0024
E/E' avr	–0.48	0.0001
E' lat	0.33	0.01
A' lat	0.35	0.006
E/E' lat	–0.46	0.0002
S' lat	0.30	0.019

LA — transverse atrial diameter; LVEF — left ventricular ejection fraction; E — early mitral inflow velocity; Et — duration of early phase of mitral inflow; At — duration of atrial phase of mitral inflow; Adt — deceleration time of mitral inflow atrial phase; Art — duration of atrial reversal flow (in pulmonary vein); Arv — velocity of atrial reversal flow (in pulmonary vein) [cm/s]; ΔAt — difference between duration of atrial reversal flow in pulmonary vein and duration of atrial phase of mitral inflow; E/Ep — ratio of peak velocity of mitral inflow early phase to propagation velocity; E' — early diastolic m.a. velocity; A' — late diastolic m.a. velocity; S' — systolic m.a. velocity; E/E' — ratio of peak velocity of mitral inflow early phase to peak velocity of early mitral annulus motion; r — correlation coefficient, the strongest correlations are bolded

tolerance was observed for left ventricular ejection fraction (LVEF; r = 0.48), duration of atrial phase of mitral inflow (At; r = 0.46) and early velocity of mitral annulus motion (E' avr; r = 0.42; Table 5).

In multivariate stepwise regression analysis, two independent predictors of exercise duration were found: age and the difference between duration of reversal flow in pulmonary vein and atrial phase of mitral inflow (ΔAt=Art–At). The results of the regression analysis can be seen in Table 6.

Reproducibility assessed for pulsed tissue Doppler measurements performed by two observers was slightly lower than for pulsed wave Doppler data. Mean coefficient of variance was 6% for tissue Doppler data (average value for velocities and durations) and 4% for pulsed wave Doppler measurements.

The measurements of propagation velocity showed acceptable reproducibility, slightly lower for atrial propagation. Coefficients of variability for interobserver measurements were 6% for early and 15% for atrial propagation, Intraobserver reproducibility was 10.2% and 13.5% respectively.

Table 6. Stepwise multivariate analysis of predictors for exercise duration. R adjusted 0.42. Coefficient of determination 0.4363.

Parameters	Coefficient	p
ΔAt (Art–At)	–1.43	< 0.0001
Age	–5.57	0.0003
LVEF, At, E/E' avr, Arv	Not included	

ΔAt — difference between duration of atrial reversal flow in pulmonary vein and duration of atrial phase of mitral inflow; LVEF — left ventricular ejection fraction; At — time of mitral inflow atrial phase; E/E' avr — ratio of peak velocity of mitral inflow early phase to peak velocity of early mitral annulus motion; Arv — velocity of atrial reversal flow (in pulmonary vein) [cm/s]

Discussion

In our study of patients who had suffered myocardial infarction, significant impairment of both systolic and diastolic parameters was predictive for advanced class of HF.

Those in a higher NYHA class were characterized by larger left atrial and ventricular dimensions, but in our population (ejection fraction range: 14––55%; mean ejection fraction: 34 ± 11%) did not differ according to right ventricular diameter (right ventricle: 25 mm in both groups). Advanced levels of diastolic dysfunction: pseudonormal and restrictive profiles were more frequent in group 2 (56% *vs*. 12%), also mean parameters of mitral inflow were in patients with severe symptoms closer to pseudonormal than delayed relaxation filling.

In those assessed as III and IV NYHA class, we observed significantly decreased velocity of early mitral inflow propagation (21 ± 7 cm/s), which corresponded with deep contractility impairment (ejection fraction: 28 ± 8%), great changes of left ventricular geometry and predominant pseudonormal pattern of filling [9, 10].

Interesting data was obtained from analysis of tissue Doppler measurements. Peak velocities of mitral annulus motion in all three phases were significantly lower in advanced HF. The significance of these differences was maintained, both for mean parameters calculated from six points of mitral annulus, and for data describing motion of lateral part of annulus. These results in the case of systolic velocity (S') correspond with lower ejection fraction in group with NYHA III and IV class, because systolic velocity of mitral annulus may have an application as a surrogate for left ventricular ejection fraction [11].

Significant difference was also detected for E/E' ratio, again similarly for averaged and lateral data. Mean value for this parameter (averaged from six points of mitral annulus) was in our study group with NYHA class III and IV: 10.5 ± 5 *vs*. 6.1 ± 1.3; in NYHA I and II class; $p < 0.001$. These values are slightly lower but show a similar trend in comparison to data published by Matsumura et al. [12] who in patients with hypertrophic cardiomiopathy observed in III NYHA class mean E/E' ratio 12 ± 4.6, in II class 7.6 ± 3.1, and in I class 6.6 ± 2.6.

The most significant negative correlation with exercise duration (ED) showed difference between duration of pulmonary vein reversal flow in atrial phase and atrial wave of mitral inflow (ΔAt; $r = -0.53$) and ratio of early wave peak velocity to early diastolic velocity of mitral annulus (E/E' avr; $r = -0.48$). High values of both parameters reflect elevated filling pressure and are connected with severe diastolic dysfunction of left ventricle. Very similar results were achieved by Matsumura et al. [12] in the aforementioned study of 85 patients with hypertrophic cardiomiopathy. Correlation coefficient with exercise tolerance measured as peak oxygen consumption for ratio of early wave peak velocity to early diastolic velocity of mitral annulus (E/E') was $r = -0.42$, $p < 0.0001$.

The highest positive correlation was found for duration of mitral inflow atrial phase (At; $r = 0.46$), peak early diastolic velocity of mitral annulus (E' avr; $r = 0.42$) and left ventricular ejection fraction (LVEF; $r = 0.48$).

In the literature, various parameters have been documented as predictors of exercise tolerance. In the study by Pepi et al. [13] of 101 patients with congestive HF of ischemic and nonischemic origin (dilated cardiomiopathy), multivariate analysis showed left ventricular ejection fraction, mitral early wave deceleration time and diastolic diameter of left ventricle as independent predictors of exercise performance. In another study of 47 patients with idiopathic or ischemic HF with a low mean ejection fraction of 28%, the independent predictors of peak oxygen consumption during exercise test were: E/A ratio, peak velocity of atrial phase of mitral inflow and mitral regurgitation grade [14].

Our study found a significant correlation between ejection fraction and ED, This may result from a relatively wide spectrum of systolic dysfunction. Shortened duration and deceleration time of atrial phase are less known but similar to early wave deceleration time indices of elevated left ventricular end-diastolic pressure and correlate with poor exercise capacity.

In multivariate stepwise regression analysis, only two independent predictors of exercise duration were found: age and the difference between duration of reversal flow in pulmonary vein and atrial phase of mitral inflow (ΔAt = Art–At). Although negative correlation of age and parameters reflecting high left ventricular filling pressure with ED seems likely, there is little data concerning this problem in recent literature. Negative correlation between left atrial volume (observed also in our study for left atrial diameter), E/E' ratio and exercise tolerance (expressed as peak oxygen consumption and exercise time) was recently documented by Arruda et al. [15] in 47 subjects with isolated diastolic dysfunction.

Limitations of the study

Limitations of our study include lack of invasive measurement of filling pressure which could prove interdependence of noninvasive indices of restrictive physiology with severe symptoms of HF. On the other hand, correlations between echocardiographic parameters reflecting filling pressure and invasive data are nowadays well documented and they can be acceptable as surrogates of invasive measurements which are burdensome for patients. Another, and in our opinion more significant, limitation is the assessment of exercise duration with simple symptom-limited treadmill test without measuring peak oxygen consumption, This was due to the unavailability of spiroergometry in our department during our study.

Our group was also small and did not include patients with severe mitral regurgitation, which additionally have an impact on exercise tolerance. We also did not analyze the impact of the extent of coronary artery lesions on ED because of the lack of angiographic data in some of our patients.

Conclusions

1. Following MI, both systolic and diastolic echocardiographic parameters differ as between subjects with mild and severe symptoms of heart failure,
2. The closest negative correlation with exercise tolerance showed pulmonary vein and tissue Doppler parameters reflecting advanced stage of diastolic impairment. Positive correlation was observed for left ventricular ejection fraction, peak early diastolic velocity of mitral annulus and duration of mitral inflow atrial phase.
3. The only independent predictors of exercise duration were age and the difference between duration of reversal flow in pulmonary vein and atrial phase of mitral inflow (ΔAt = Art–At).

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References

1. Naqvi TZ, Padmanabhan S, Rafii F, Hyuhn HK, Mirocha J. Comparison of usefulness of left ventricular diastolic versus systolic function as a predictor of outcome following primary percutaneous coronary angioplasty for acute myocardial infarction. Am J Cardiol, 2006; 15: 160–166.
2. Wierzbowska-Drabik K, Krzemińska-Pakuła M, Drożdż J et al. Enlarged left atrium is a simple and strong predictor of poor prognosis in patients after myocardial infarction. Echocardiography, 2008; 25: 27–35.
3. Eriksson SV, Caidahl K, de Faire U et al. Diastolic and systolic function as predictors of exercise capacity after myocardial infarction in young men. Cardiology, 1998; 90: 8–12.
4. Hillis GS, Moller JE, Pellikka PA et al. Noninvasive estimation of left ventricular filling pressure by E/e' is a powerful predictor of survival after acute myocardial infarction. J Am Coll Cardiol, 2004; 43: 360–367.
5. Hillis GS, Ujino K, Mulvagh SL et al. Echocardiographic indices of increased left ventricular filling pressure and dilation after acute myocardial infarction. J Am Soc Echocardiogr, 2006; 19: 450–456.
6. Kidawa M, Coignard L, Drobinski G et al. Comparative value of tissue Doppler imaging and m-mode color Doppler mitral flow propagation velocity for the evaluation of left ventricular filling pressure. Chest, 2005; 128: 2544–250.
7. Oh JK, Appleton CP, Hatle LK et al. The noninvasive assessment of left ventricular diastolic function with two-dimensional and Doppler echocardiography. J Am Soc Echocardiogr, 1997; 10: 246–270.
8. Rakowski H, Appleton CP, Chan KL et al. Canadian consensus recommendations for the measurement and reporting of diastolic function by echocardiography: From the Investigators of Consensus on Diastolic Dysfunction by Echocardiography. J Am Soc Echocardiogr, 1996; 9: 736.
9. Wierzbowska K, Kasprzak JD, Drożdż J, Wejner-Mik P, Krzemińska-Pakuła M. The assessment of mitral inflow propagation velocity in the diagnosis of advanced left ventricular diastolic dysfunction. Kardiol Pol, 2003; 59: 230–234.
10. Wierzbowska-Drabik K, Kasprzak JD, Krzemińska-Pakuła M. Propagation velocity, contractility and prognosis in patients with delayed relaxation. Int J Cardiol, 2006; 113: 111–112.
11. Ruan Q, Nagueh SF. Usefulness of isovolumic and systolic ejection signals by tissue Doppler for the assessment of left ventricular systolic function in ischemic or idiopathic dilated cardiomyopathy. Am J Cardiol, 2006; 97: 872–875.
12. Matsumura Y, Elliot PM, Virdee MS et al. Left ventricular diastolic function assessed using Doppler tissue imaging in patients with hypertrophic cardiomyopathy: relation to symptoms and exercise capacity. Heart, 2002; 87: 247–251.
13. Pepi M, Agostini P, Marenzi G et al. The influence of diastolic and systolic function on exercise performance in heart failure due to dilated cardiomyopathy or ischemic heart disease. Eur J Heart Fail, 1999; 1: 161–167.
14. Lapu-Bula R, Robert A, De Kock M et al. Relation of exercise capacity to left ventricular systolic function and diastolic filling in idiopathic or ischemic dilated cardiomyopathy. Am J Cardiol, 1999; 83: 728–734.
15. Arruda AL, Pellika PA, Olson TP, Johnson BD. Exercise capacity, breathing pattern, and gas exchange during exercise for patients with isolated diastolic dysfunction. J Am Soc Echocardiogr, 2007; 20: 838–846.