Correlations Between Echo-Doppler Indexes and Exercise Testing in the Elderly

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Introduction: The ageing heart is characterised by an abnormal diastolic filling curve due to prolonged relaxation. The purpose of this study was to investigate a possible correlation between exercise capability and diastolic dysfunction of the left ventricle (LV) in elderly people by exercise testing (Ext) and Doppler echocardiography.

Methods: We studied 20 persons (mean age 74±4.02 years); free of hypertension, coronary artery disease, heart failure, chronic atrial fibrillation and LBBB. All subjects underwent an echo doppler study and exercise test using the standard Bruce protocol. The following doppler indexes were measured: 1. E and A maximum velocities, 2. E/A ratio, 3. Deceleration time (DT), 4. Isovolumic relaxation time (IVRT). We also recorded: a)exercise duration (Dex), b) maximum blood pressure (BPmax), c) maximum heart rate (HRmax). Possible correlations between echo doppler and Ext indexes we determined using Pearson's test.

Results: All subjects had a negative exercise test and a transmitral flow pattern of prolonged relaxation type. We noticed a negative correlation between DT and a) Dex (r: -0.652 p: 0.041), b) BPmax (r: -0.912 p: 0.000) and c) HRmax (r: -0.743 p: 0.014). No other correlation had been found between exercise test and doppler indexes. DT was the only independent variable contributing to stress test duration that was retained in a multivariate analysis (F: 5.905 p: 0.041, β: -0.271, constant: 11.824), (the variables analyzed were: age, echocardiographic indexes of diastolic function and clinical indexes at rest).

Conclusions: It seems that the functional ability of the elderly can be estimated by the deceleration time (DT), (as the DT increases the maximum Dex and the maximum inotropic and chronotropic response decreases). The independent correlation of DT with stress test duration was confirmed by multivariate analysis.

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Decreased compliance of the left ventricle and pathologic relaxation lead to alterations in the diastolic filling of elderly people. Several studies have shown that altered diastolic filling of prolonged relaxation type is common among the elderly[1-2] and that changes of diastolic function indexes related to ageing were found to be independent of the mass of the left ventricle, the heart rate, the contractility and the loading state[5]. The increased collagen content of the ageing left ventricle[3] leads to decreased compliance, while the disturbances of cellular Ca^{++} kinetics deregulate relaxation[4]. Elderly people with diastolic dysfunction are usually asymptomatic at rest and symptomatic on effort.

The present study was planned to investigate potential correlations between exercise capacity and the echocardiographic indexes of left ventricle diastolic dysfunction in elderly persons with normal systolic function.

Material and Method

We studied 20 subjects (12 men and 8 women) with left ventricle diastolic dysfunction, (mean age 74.8±4.02 years).

The inclusion criteria were: 1. Age ≥70 years 2. Normal systolic left ventricle function (EF ≥55%) 3. Transmitral doppler flow E/A ratio <1 (where E is the maximal velocity of E wave and A the maximal velocity of A wave).

The exclusion criteria included: 1. Hypertension, 2. coronary artery disease, 3. severe valvular heart disease, 4. chronic atrial fibrillation, 5. LBBB, 2nd or 3rd degree AV block, 6. permanent pacemaker, 7. technically difficult echocardiographic study.

Informed consent was obtained from all the subjects enrolled in the study.

After a detailed history and clinical examination, every subject underwent an exercise stress test using the Bruce protocol with maximum heart rate calculated as 220 bpm minus the age. A complete echocardiographic study (M-mode, 2D, Doppler) was done with the patients reclined on the left side. Parasternal and apical views were taken using a Hewlett Packard Sonos 1500 with a 2.5 MHz transducer. The measurements of wall thickness, internal dimensions and EF were taken from the M- mode recording. The transmitral flow was recorded during the diastolic period with the sampling volume of the pulsed doppler positioned 0.5-1 cm from the tips of the mitral leaflets. Maximum velocities E and A, E/A, and the deceleration time of the maximum velocity of protodiastolic filling (DT) were measured. The isovolumic relaxation time (IVRT) was measured from the end of aortic flow to the beginning of transmitral flow with the sampling volume of the pulsed doppler positioned on the LV outflow tract in the apical 5-chamber view with simultaneous recording of mitral and aortic flow.

Statistical analysis

Testing of bivariate correlation between the stress test data and the diastolic indexes was done with the Pearson statistic. Testing for independent correlations was done by means of the forward linear regression model. P values <0.05 were considered statistically significant.

Table 1. Results of the exercise test.

Dex (min)	BPmax (mmHg)	HRmax (bpm)
6.65±1.9	162±13.2	145.5±8.2

Dex: Duration of exercie, BPmax: Maximum blood pressure, HRmax: Maximum heart rate.

Results

All subjects were subjected to an exercise stress test of 6.65±1.9 min duration. The stress test was negative in all instances. Reasons for termination of the test were dyspnea and severe fatigue. None of the subjects had angina or ischemic ECG changes. Stress test duration (Dex), maximum blood pressure (BPmax) and maximum heart rate (HRmax) are shown in table 1.

All subjects had transmitral flow signals indicative of prolonged relaxation. The values of left ventricle diastolic function indexes and ejection fraction (EF) are shown in table 2. All subjects had decreased max. E-wave velocity, increased maximum A-wave velocity, E/A <1, DT and IVRT prolongation and normal systolic function.

The correlations between the echo-doppler indexes and the exercise test parameters are given in table 3. We noticed a negative correlation between the deceleration time (DT) and: 1. the exercise duration (r: -0.652, p: 0.041) (Figure 1) 2. the BPmax (r: -0.912, p: 0.000) 3. the HRmax (r: -0.743, p: 0.014). No other correlations were found between exercise test data and the rest of the doppler - echo indexes.

The following variables were calculated in the statistic model of forward linear regression against exercise test duration: age, echo-doppler indexes of diastolic function (E, A, E/A, DT, IVRT) clinical index-

Table 2. Diastolic paremeters and EF.

E (m/sec)	A (m/sec)	E/A	DT (ms)	IVRT (ms)	EF (%)
0.6±0.2	0.87±0.2	0.69±0.1	258±60.7	104±20.1	63±4.2

E: Peak velocity of mitral E wave, A: Peak velocity of mitral A wave, DT: Deceleration time, IVRT: Isovolumic relaxation time, EF: Ejection fraction.

Table 3. Correlations between echo-doppler indexes and exercise stress testing.

	E	A	E/A	DT	IVRT
Dex	r: 0.029 p: NS	r: -0.028 p: NS	r: 0.059 p: NS	r: -0.652 p: 0.041	r: 0.035 p: NS
BPmax	r: -0.567 p: NS	r: -0.387 p: NS	r: -0.382 p: NS	r: -0.912 p: 0.000	r: -0.159 p: NS
HRmax	r: 0.437 p: NS	r: -0.581 p: NS	r: 0.087 p: NS	r: -0.743 p: 0.014	r: -0.271 p: NS

Dex: Duration of exercise, BPmax: Maximum blood pressure, HRmax: Maximum heart rate, E: Peak velocity of mitral E wave, A: Peak velocity of mitral A wave, DT: Deceleration time, IVRT: Isovolumic relaxation time.

es at rest (systolic BP, diastolic BP, heart rate). The only variable that was maintained by the statistical analysis as independent contributing variable in the duration of exercise test was the deceleration time (DT) (F: 5,905, p: 0,041, β: -0.271, constant 11.824).

According to this finding, elderly people could be classified into two groups: a. Those that achieved less than 6 min of exercise test had an average DT of 317.5±45 msec (270-370 msec). b. Those that achieved more than 6 min of exercise had an average DT of 222±26 msec (180-250 msec).

Discussion

The diastolic function of the left ventricle mainly reflects the interaction between relaxation, compliance and filling load. A simple, quick estimation of diastolic function is given by doppler-echocardiography. Advanced age is related to ventricular stiffness, poor relaxation, decreased maximum velocity of early-diastolic filling (E) and higher velocity of the atrial component of filling (A) indicative of prolonged relaxation[5-6]. In elderly people slow relaxation results in a decreased velocity and prolonged early-diastolic filling, prolongation of intraventricular relaxation time (IVRT) and a DT similar or longer compared to younger people.

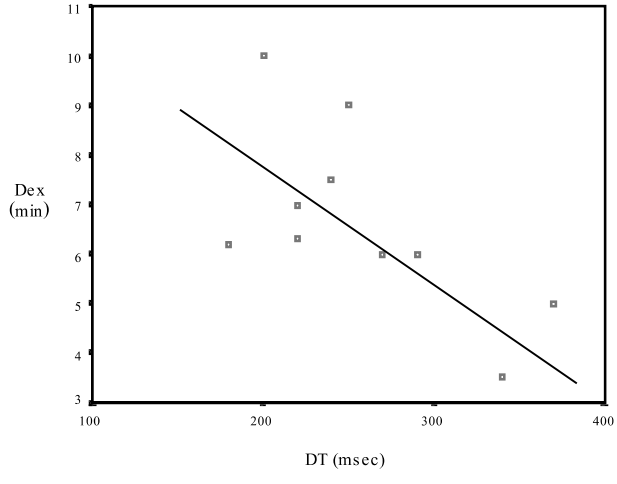

Figure 1. Graphic representation of the negative correlation between stress test duration (Dex) and deceleration time (DT), (r =-0.652, p= 0.041).

Ventricular relaxation is an active process during which Ca^{++} that was released to the sarcoplasm during systole is removed through the Ca^{++} pump by 60-80% to the sarcoplasmic reticulum during diastole and by 20-40% of the extracellular space through the Na^{+}/Ca^{++} pump. Both mechanisms restore the intracellular concentration of Ca^{++} after contraction. The Ca^{++} pump action is impaired with increasing age leading to intracellular overloading of Ca^{++} and worsening of ventricular relaxation. Ming-Jui Hung et al.[7] showed that a 3-month administration of verapamil to healthy elderly people with prolonged relaxation diastolic dysfunction can improve both exercise tolerance and diastolic left ventricle function by shortening the IVRT.

The E/A ratio is the simplest and most commonly used index of diastolic filling. In a subgroup of 703 healthy subjects aged ≥65 enrolled in the Cardiovascular Health Study[8] the velocities of early and delayed (atrial) diastolic filling were measured. Every 10-year increase of age was followed by an average decrease of early-diastolic filling velocity (E) by 3.3 cm/s and by an increase of late-diastolic filling velocity (A) by 6.5 cm/s.

Moreover, it is recognised that more than 1/3 of the patients with congestive heart failure (CHF) have a normal systolic function and the clinical symptoms are attributed to diastolic dysfunction[9-11]. A pathologic myocardial relaxation or increased wall stiffness can increase the resistance to diastolic filling of the left ventricle with subsequent increase of left atrial and pulmonary pressures creating symptoms of CHF. Paul Marantz et al[11], using a multivariate analysis statistic, studied 114 subjects with an average age of 75.5 years and found no relation between delayed ventricular filling (E/A <1) and clinically manifest CHF. In another observational study of elderly people (>70 years old) who were discharged from hospital with a diagnosis of CHF, those with good systolic function had a lower short-

term mortality than those with systolic dysfunction, although the long-term mortality was similar[12].

In 2671 subjects aged ≥ 65 Gerard Aurigemma et al[13] studied the presence of echocardigraphic-doppler indexes of diastolic function that could predict the appearance of CHF. The maximum velocity E was positively related to the manifestation of CHF (170 subjects developed CHF in the next 5.2 years). The same was true for the marginal values of the E/A ratio (i.e. 1.5 >E/A <0.7).

In a recent 3-year follow-up study[14] of a large population of middle-aged and elderly people the E/A ratio >1.5 was positively related to an increased risk of overall and cardiac death (there was a two-fold increase in overall mortality and a three-fold increase in cardiac mortality). The relation between E/A >1.5 and cardiac mortality was also present in subjects without a history of CHF and in those with an EF ≥40%, showing that increased filling pressure predisposes to a poor outcome, even in the absence of symptoms or of severe systolic dysfunction.

Left atrial pressure is increased during exercise and this can contribute to the appearance of dyspnea on effort[15]. In the present study we evaluated the relation between functional parameters of exercise and echocardiographic indexes in asymptomatic elderly people with diastolic dysfunction of prolonged relaxation type. A basic echocardiographic study and exercise stress test was done in 20 elderly subjects with no cardiovascular disease. A negative correlation was noticed between DT and Dex, BPmax, HRmax. Deceleration time (DT) is the interval between the peak of the E-wave and the intersection of the deceleration slope of the above wave with the baseline; it reflects the speed of cessation of early-filling according to the rate of relaxation and the compliance of the left ventricle. It seems that DT is a good estimator of the functional capacity in elderly people. The longer the deceleration time the shorter the maximum duration, the maximum inotropic and maximum chronotropic response to exercise testing.

The independent relation between DT and Dex was confirmed in a multivariate analysis statistic. The variables entered into the model were: age, echo-indexes (E, A, DT, IVRT), BP at rest and HR at rest. Those that did not achieve more than 6 minutes of exercise had a DT >270 msec.

Limitations of the study

1. The number of participants is small. A larger sample is required in order to reach definitive conclusions.
2. Exercise was performed without oxygen consumption recording. The co-operation of the elderly and the subjective interpretation of symptoms during the test may have influenced the duration of the exercise.
3. The echocardigrahic indexes are sensitive to the heart rate and the loading state of the left ventricle. The gold standard method for the evaluation of diastolic dysfunction is cardiac catheterization and the assessment of the pressure-volume curves at rest and during exercise.

Conclusions

1. The ageing heart is characterised by an abnormal curve of diastolic filling due to prolonged relaxation.
2. The deceleration time of rapid filling (DT) is negatively related: to a) exercise duration b) maximum BP and c) maximum HR in elderly people with a transmitral flow pattern indicative of prolonged relaxation. DT is a good estimator of the functional capacity of elderly people; it shows an independent negative relation with exercise duration. Values of DT >270 identify elderly subjects that cannot achieve more than 6 min of exercise testing and have prolonged LV relaxation.

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