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Doppler Echocardiography in Dilated Cardiomyopathy: Diastolic and Combined Systolic/Diastolic Parameters Offer More Detailed Information on Left Ventricular Global Dysfunction than Systolic Parameters

J. B. Dahm¹, E. Kuon², D. Vogelgesang¹, H. Voelzke¹, A. Hummel¹

Although diastolic dysfunction is the initial alteration in dilated cardiomyopathy (DCM), and systolic and diastolic dysfunctions generally coexist during the clinical course of DCM, left ventricular ejection fraction (LV-EF) as an entirely systolic parameter is commonly used to assess LV-function. Several studies have shown greater correlation between clinical status and diastolic echocardiographic parameters. A new index, systolic/diastolic performance [(ICT+IRT)/ET; ICT = isovolumetric contraction time; IRT = isovolumetric relaxation time; ET = ejection time] combines diastolic and systolic parameters and is less influenced by heart rate and mitral regurgitation. The present study was designed to evaluate the accuracy in detecting left ventricular global dysfunction by different echocardiographic measures, in correlation to NYHA-grade and LV-EF (angiography) in DCM.

Left ventricular end diastolic diameter (LVEDD), LV-EF, A-, E-dec.-time, and systolic/diastolic performance were obtained by Doppler echocardiography and compared to NYHA-grade and LV-EF (angio) in 68 patients with DCM. LV-EF (echo) values were dispersed widely and showed no correlation to NYHA-grade. In contrast LV-EF (angio), LVEDD, E-, A-dec.-time, and systolic/diastolic performance showed a high correlation to NYHA-grade.

The successive shortening of E/A-dec.-time due to increasing LV filling pressures and the increasing systolic/diastolic performance contribute more detailed information about clinical status and can be carried out quickly and non-invasively. *J Clin Basic Cardiol* 2002; 5: 189–92.

Key words: Doppler echocardiography, diastolic function, systolic function, systolic/diastolic performance, dilated cardiomyopathy

Although diastolic dysfunction is the initial alteration in dilated cardiomyopathy (DCM), and systolic and diastolic dysfunctions generally coexist during the clinical course of DCM, left ventricular ejection fraction (LV-EF) as an entirely systolic parameter is commonly used to assess LV-function in patients with dilated cardiomyopathy. Traditional parameters obtained by mechanocardiography revealed long ago that systolic dysfunction is not only reflected as a decrease in ventricular ejection fraction (LV-EF) – mostly assessed by echocardiography or angiography – but also as a prolongation of the pre-ejection and shortening of ejection time (= isovolumetric contraction (ICT)) and relaxation time (IRT). This phenomenon can also be assessed by Doppler echocardiography. The diastolic dysfunction is reflected in alterations in the pattern of the inflow velocity of the left ventricle in early and late diastole [1]. Several studies have revealed a higher correlation between clinical status and echocardiographic parameters, reflecting entirely diastolic dysfunction (E and A deceleration time) and including the disadvantage that pure diastolic parameters are more influenced by heart rate and mitral regurgitation [2]. A new index, systolic/diastolic performance, combines diastolic and systolic parameters and accordingly shows no significant influence of heart rate or of the mitral regurgitation that is often present in congestive heart failure [3].

The present study was designed to compare the accuracy in detecting left ventricular global dysfunction by measurement of systolic (LV-EF) or diastolic function (E and A deceleration time) alone, and in employing combined systolic and diastolic parameters (systolic/diastolic performance) in correlation to NYHA-grade and left ventricular ejection fraction

(LV-EF), as obtained by angiography in patients with dilated cardiomyopathy, with or without mitral regurgitation.

Methods

Patients

A total of 68 patients with idiopathic cardiomyopathy were selected to study and compare three different echocardiographic methods of assessing left ventricular function (LV-function): LV-EF assessed by Simpson's method, E and A deceleration time, and systolic/diastolic performance (isovolumetric contraction time + isovolumetric relaxation time/ejection time) [(ICT+IRT)/ET] in comparison to LV-EF obtained by angiography. All patients were classified according to their clinical status in four groups: Group I: NYHA-grade I (n = 18); Group II: NYHA-grade II (n = 17); Group III: NYHA-grade III (n = 19); and Group IV: NYHA-grade IV (n = 14). None of the selected patients demonstrated atrial fibrillation, atrio-ventricular block, or valvular disease.

Echocardiographic examination

A two-dimensional, pulsed, continuous-wave- and color-flow Doppler echocardiographic examination was performed using commercially available ultrasound instrumentation (System FIVE, GE Medical Systems, Milwaukee, WI). Left ventricular dimensions were measured at mid-ventricular level from the M-mode obtained in the parasternal long or short-axis view. LV-EF was calculated using Simpson's method (apical view).

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Doppler examination

Mitral inflow velocity was recorded from the apical four-chamber view. The pulsed Doppler sample volume was positioned at the tips of the mitral leaflets. Left ventricular outflow velocity was recorded from the apical long-axis view (or apical five-chamber view), with the sample volume positioned just below the aortic ring.

Echo/Doppler measurements

All echo/Doppler-parameters were measured from monitor recordings. For all parameters, three consecutive beats were measured. Systolic/diastolic performance [(ICT+IRT)/ET] was calculated following analysis of Doppler time intervals as described by Tei et al. [3] (Fig. 1). Mitral closure-to-opening interval is characterized as the time from cessation to the beginning of mitral inflow. Ejection time (ET) was measured as the duration of left ventricular outflow. Isovolumetric contraction time (ICT) plus isovolumetric relaxation time (IRT) were calculated and systolic/diastolic performance was assessed by the following equation: (ICT+IRT)/ET.

Velocities from mitral inflow in early (E) and late diastole (A) were measured, and deceleration time was defined as the time from the E- or A-peak to intersection with the baseline. Deceleration time was not assessed if E and A were summated (tachycardia).

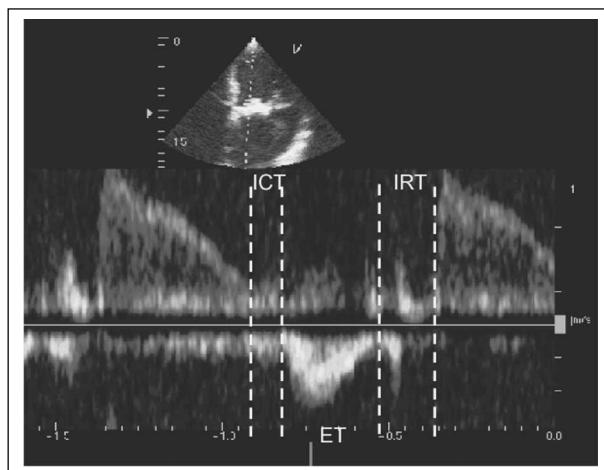


Figure 1. Calculation of the systolic/diastolic performance [(ICT+IRT)/ET]: Mitral closure-to-opening interval (a) is characterized as the time from cessation to the beginning of mitral inflow. Ejection time (ET) is measured as the duration of left ventricular outflow (b). Isovolumetric contraction time (ICT) + isovolumetric relaxation time (IRT) is calculated by subtracting 'b' from 'a' divided by 'b' [(ICT+IRT)/ET = (a-b)/b].

Table 1. Patients' characteristics at baseline

		NYHA I	p-value	NYHA II	p-value	NYHA III	p-value	NYHA IV
Patients	(n)	18	ns	17	ns	19	ns	14
Age	(years)	51 ± 15	ns	56 ± 16	ns	55 ± 18	ns	53 ± 13
Male	(n)	11	ns	12	ns	11	ns	9
Heart rate	(beats/min)	63 ± 9	ns	70 ± 11	ns	74 ± 12	ns	81 ± 17*
Systolic BP	(mmHg)	129 ± 20	ns	123 ± 16	ns	117 ± 13	ns	110 ± 11#
Diastolic BP	(mmHg)	76 ± 8	ns	74 ± 7	ns	73 ± 9	ns	70 ± 9
Mitral regurg. I	(%)	5.5	< 0.1	11.8	< 0.1	15.9*	n.s.	14.2*
Mitral regurg. II	(%)	11.1	< 0.1	17.6	< 0.1	21.0*	n.s.	21.4*
Mitral regurg. III	(n)	16.7	< 0.1	23.5	n.s.	21.0	< 0.1	28.6*

* = $p < 0.05$ as compared to NYHA I, # = $p < 0.1$ as compared to NYHA I; BP = blood pressure; Mitral regurg. = mitral valve regurgitation

Statistical analysis

Continuous data are expressed as mean ± standard deviation (SD) and categorical data as frequency percentages. Differences in category variables were analysed by chi-square analysis and differences in continuous variables by Student's bilateral t-test (the most common version). Probability values < 0.05 were significant.

Results**Baseline components**

Among the many baseline comparisons, only a few differed significantly ($p < 0.05$) (Tab. 1). Although heart rate did not differ significantly among the impending NYHA classes, heart rate was significantly greater and blood pressure lower in NYHA IV (and III) than in NYHA I (and II). Mitral regurgitation (incidence and severity) was significantly more common in higher than in lower NYHA classes.

Doppler echocardiographic data

Figure 1 shows an example of measurement of systolic/diastolic performance [(ICT + IRT)/ET] in a patient with NYHA class I.

Figures 2–7 summarize the results of LV-EDD (Fig. 2), LV-EF (echo) (Fig. 3), LV-EF (angio) (Fig. 4), Doppler time intervals (E and A deceleration time) (Figs. 5, 6), and systolic/diastolic performance [(ICT+IRT)/ET] (Fig. 7) in comparison to NYHA class. The Doppler time intervals (E and A deceleration time) were significantly shorter with increasing NYHA class (Figs. 5, 6), and systolic/diastolic performance [(ICT+IRT)/ET] was significantly greater with increasing NYHA class (Fig. 7).

Analogous to Tei et al. [3], there was no correlation between heart rate and mitral regurgitation and systolic/diastolic performance [(ICT+IRT)/ET].

Echocardiographically obtained LV-EF showed no correlation to the NYHA class of patients with congestive heart failure (Fig. 3), in contrast to the angiographically obtained LV-EF, which correlated significantly with NYHA class (Fig. 4). LV-EDD parameters correlated significantly among the higher and lower NYHA grades (Fig. 2).

Reproducibility of measurements

Table 2 shows the mean interobserver difference of the measured parameters. Measurements of systolic/diastolic performance [(ICT+IRT)/ET] and diastolic parameters were well correlated on separate occasions and between different observers.

Discussion

Global left ventricular function depends on a combination of both ventricular filling (diastolic function) and ejection (systolic function). Most indices, however, focus on systolic dysfunction, or separately on systolic or diastolic functions. LV-EF is the most commonly used parameter for the assessment of left ventricular dysfunction. It has consistently proven to be a good indicator of cardiovascular function. Obtained as it is by different techniques,

however, it relies on various ventricular factors such as LV geometry, or is based on erroneous assessment of ventricular contractility in patients with aortic or mitral regurgitation. These conditions are often present in patients with conges-

Table 2. Intraobserver differences (coefficient of variation) of the different morphological and functional parameters

	%
LVEDD	8.3 ± 6.7
LV-EF (Angio)	9.1 ± 8.0
LV-EF (Echo)	7.8 ± 4.5
Tei-index	4.8 ± 4.5
E-dec. time	4.8 ± 4.1
A-dec. time	4.7 ± 4.1

LVEDD = left ventricular end diastolic diameter; LV-EF (angio)/(echo) = left ventricular ejection fraction obtained by angiography/echocardiography; E-dec. = E-deceleration; A-dec. = A-deceleration

tive heart failure. Additional reliable assessments of left ventricular ejection fraction depend significantly on satisfactory echo conditions. This may represent one reason for the widely dispersed echocardiographic LV-EF findings in our study which showed no correlation to NYHA grades and accordingly only poorly reflected the clinical status of patients with congestive heart failure.

Systolic/diastolic performance that combines systolic and diastolic parameters reflects better "global" LV-function than the isolated evaluation of either ejection or relaxation. It had earlier been shown that isovolumetric contraction time (ICT), or isovolumetric relaxation time (IRT) accurately reflect systolic or diastolic function [4, 5]. Prolongation of active contraction and relaxation (ICT and IRT) is a result of myocardial processes in congestive heart failure (eg, impaired calcium influx and efflux). Initially, prolonged relaxation is associated with increased isovolumetric relaxation time. If ventricular dysfunction progressively worsens, isovolumetric

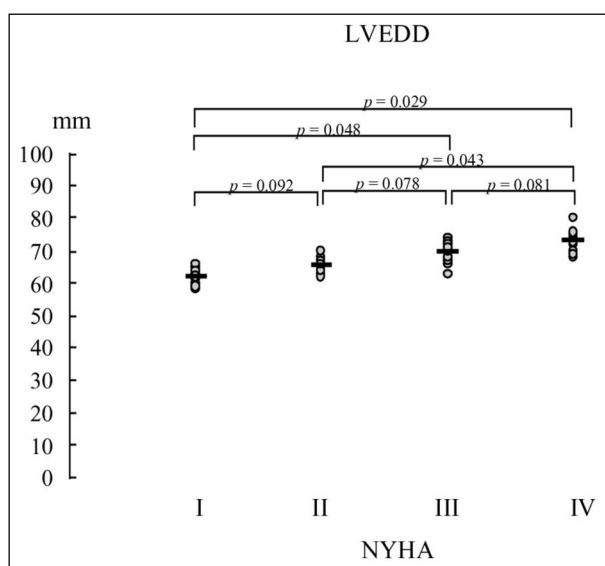


Figure 2. Left ventricular enddiastolic diameter (LVEDD) measurements obtained by echocardiography of the 68 patients in the different NYHA-groups.

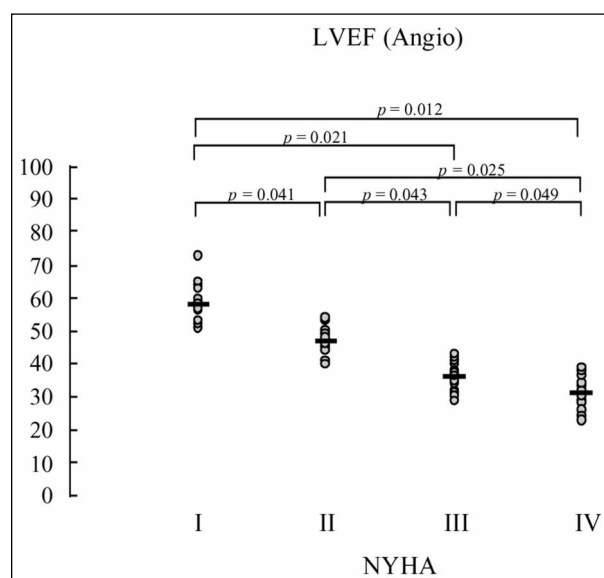


Figure 4. Left ventricular ejection fraction (LV-EF) obtained by angiography of the 68 patients in the different NYHA-groups.

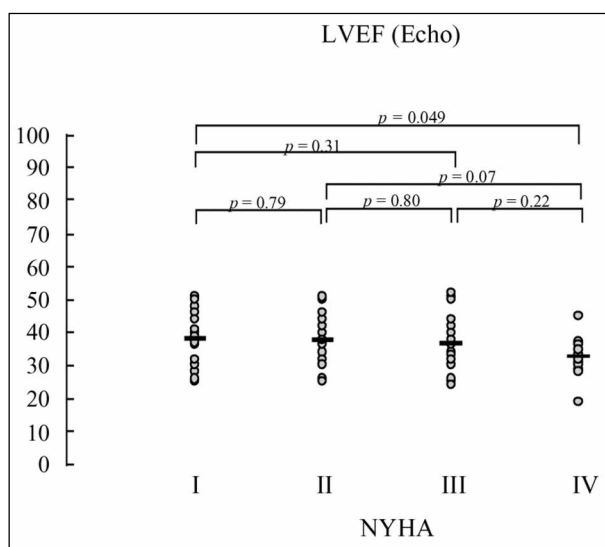


Figure 3. Left ventricular ejection fraction (LV-EF) obtained by echocardiography (Simpson's method) of the 68 patients in the different NYHA-groups.

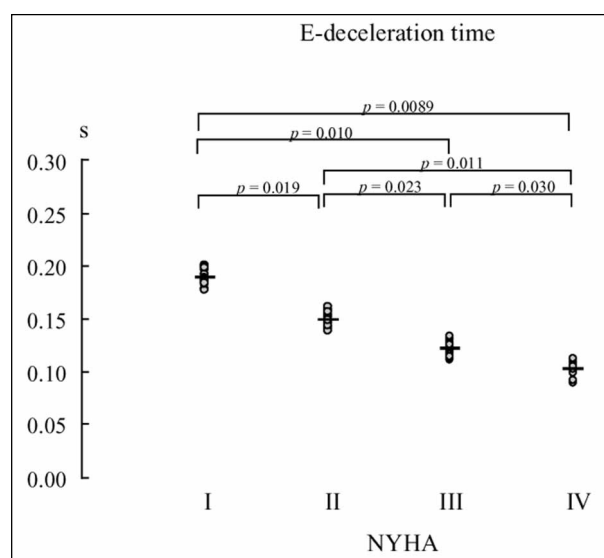


Figure 5. E-deceleration time of the 68 patients in the different NYHA-groups.

relaxation time will also be influenced by factors other than relaxation: eg, left atrial pressure and degree of mitral regurgitation. Progressive lengthening of the sum of isovolumetric relaxation time and isovolumetric contraction time, however, compensates for the variable change in isovolumetric relaxation time, as LV dysfunction continuously worsens. The progressive shortening of ejection time as LV dysfunction worsens renders systolic/diastolic performance index independent of changes in each individual component of the index. In contrast, solely diastolic or systolic parameters are more affected by mitral regurgitation (eg, ICT prolongation and IRT shortening). Analogous to Tei et al. [3], we failed to find correlation between heart rate, blood pressure, and systolic/diastolic performance index. Apparently, no interference of systolic/diastolic performance index took place as a result of mitral regurgitation to any extent.

Isovolumetric contraction and relaxation time (ICT and IRT) can be easily determined by Doppler echocardiography, which enables a high degree of reproducibility. In our study we observed only minimal variability upon measurement of these intervals by different observers.

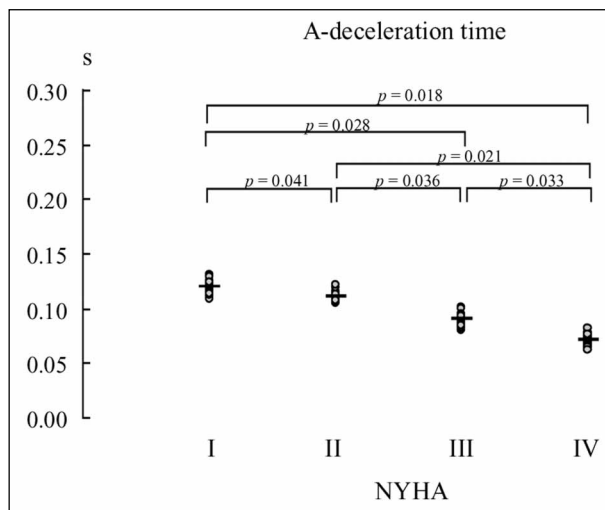


Figure 6. A-deceleration time of the 68 patients in the different NYHA-groups.

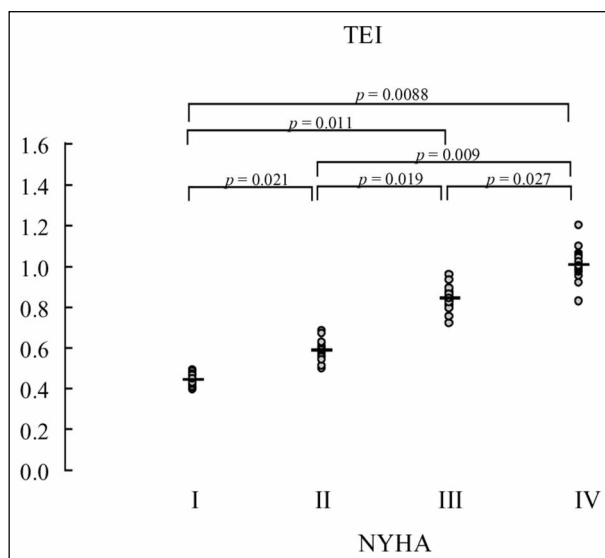


Figure 7. The systolic/diastolic performance (Tei-index) of the 68 patients in the different NYHA-groups

Conclusions

Echocardiographically obtained measurements of systolic left ventricular function (LV-EF) are often erroneous, widely dispersed and lacking in significant correlation to NYHA grades. This is in contrast to techniques involving angiographically obtained left ventricular ejection fractions, diastolic parameters alone, or combined systolic/diastolic parameters (systolic/diastolic performance). The successive shortening of E and A deceleration times owing to increasing LV filling pressures and increasing systolic/diastolic performance indices correlate significantly to NYHA grades and the process of declining LV-function. In contrast to solely diastolic parameters, however, systolic/diastolic performance is not influenced by heart rate or mitral regurgitation, which is often present in congestive heart failure. Both E and A deceleration times, as well as systolic/diastolic performance, are technically easy to obtain and highly reproducible.

Because assessment of diastolic LV-function offers additional information on prognosis, echocardiographic measurement of diastolic parameters or systolic/diastolic performance indices contributes more detailed information on LV-function. These procedures can be carried out quickly and non-invasively, in contrast to angiographically obtained LV-EF.

Study Limitations

As an exception to general procedure, we investigated patients in sinus rhythm. We followed this approach because diastolic parameters are altered by heart rate, and because systolic/diastolic performance is not principally altered by heart rate, blood pressure, valve disease, or atrial fibrillation. Another justification was that the purpose of our study was to accomplish a general evaluation of all echocardiographically obtainable left ventricular parameters of LV-function. Further studies are necessary to establish whether the solely diastolic parameters (E and A deceleration time), or systolic/diastolic performance, can be used as accurately in situations such as profound tachycardia, extremely low blood pressure, or in patients with primary diastolic dysfunctions such as hypertrophic cardiomyopathy and restrictive cardiomyopathy. Finally, the reliability of this approach must be evaluated in cases entailing arrhythmias such as atrioventricular block and atrial flutter, in which mitral inflow may be significantly affected.

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