

## Original Research

# The Clinical Value of Mitral A-Wave Deceleration Time in the Prediction of a Long-Term Adverse Outcome in Patients with Myocardial Infarction

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**Introduction:** Mitral A-wave deceleration time (Adt) is a promising Doppler parameter for the evaluation of left ventricular (LV) diastolic function. The aim of the present study was to investigate the long-term prognostic value of Adt in relation to the development of heart failure and cardiac death in the setting of the first acute myocardial infarction (MI).

**Methods:** Conventional Doppler echocardiographic study and Adt measurements were performed in 105 patients (age  $60 \pm 10$  years, 77 men) 8.07  $\pm$  0.96 days post MI. Patients were divided into three groups according to Adt duration: group 1 with Adt  $\leq 70$  ms, group 2 with  $70 \text{ ms} < \text{Adt} < 115$  ms, and group 3 with Adt  $\geq 115$  ms.

**Results:** Patients of groups 1 (Adt:  $64 \pm 5$  ms, n=11) and 3 (Adt:  $123 \pm 8$  ms, n=38) presented characteristics of restrictive physiology or impaired relaxation, respectively, while patients of group 2 (Adt:  $92 \pm 9$  ms, n=56) had near to normal LV filling characteristics. Patients were followed up for a mean of 44.7 months. Heart failure was found in 4 patients (36%) in group 1 and 6 (16%) in group 3, whereas the patients in group 2 were free of heart failure. Cardiac death occurred in 4 patients (36%) in group 1, 3 (7.9%) in group 3 and 2 (3.6%) in group 2. Kaplan-Meier survival curves indicated that patients with Adt  $\leq 70$  ms or Adt  $\geq 115$  ms had more frequent cardiac events and a significantly shorter event-free survival period in comparison with those with  $70 \text{ ms} < \text{Adt} < 115$  ms ( $p=0.0017$ ). Cox analysis showed that Adt  $\leq 70$  ms ( $p=0.002$ ), Adt  $\geq 115$  ms ( $p=0.02$ ), restrictive LV filling pattern ( $p=0.003$ ), anterior wall MI ( $p=0.02$ ), ejection fraction ( $p=0.03$ ), age ( $p=0.04$ ), and treatment with angiotensin converting enzyme inhibitors ( $p=0.009$ ) were independent predictors of outcome.

**Conclusions:** Adt appears to be a strong and independent predictor of heart failure or cardiac death following a MI. A shortened Adt  $\leq 70$  ms is associated with higher rates of both cardiac death and heart failure, while a prolonged Adt  $\geq 115$  ms is associated with heart failure only.

**L**eft ventricular (LV) diastolic dysfunction is a common disorder in patients with myocardial infarction (MI) and has been reported to have independent prognostic value.<sup>1-6</sup> Doppler echocardiography is widely used for the non-invasive assessment of diastolic filling abnor-

malities. Development of a restrictive LV filling pattern after MI has been shown to be a strong independent predictor of an adverse outcome<sup>2,4-6</sup> and to be predictive of LV remodelling after anterior MI.<sup>7</sup> However, because of the confounding effects of LV relaxation and LV compliance on the mitral

inflow, an apparently normal filling pattern may be seen in patients with advanced diastolic dysfunction.

Recently, tissue Doppler imaging of mitral annular motion and colour M-mode Doppler flow propagation have been proposed as a means of correcting for the influence of myocardial relaxation on transmitral flow. The combined assessment of mitral valve velocities with these techniques allows better estimation of LV filling pressure<sup>8,9</sup> and prediction of outcome following MI.<sup>6</sup> It seems that the evolution of the above techniques may have hindered the evaluation and application of a conventional late diastolic Doppler variable of transmitral flow velocity, the mitral A-wave deceleration time (Adt).

Adt has been reported as a useful variable for the prediction of elevated LV end-diastolic pressure<sup>10,11</sup> and detection of the type of LV diastolic dysfunction in patients with acute MI.<sup>12</sup> Although the prognostic value of the mitral E-wave deceleration time (Edt) has been extensively studied in various settings,<sup>2,4-7,13-16</sup> data are still lacking regarding the equivalent potency of Adt. On these grounds, the present study aimed to investigate the long-term prognostic value of Adt in patients who survived the acute phase of MI in relation to the development of congestive heart failure and cardiac death.

## Methods

### Patients

Our study design included a total of 110 survivors of first acute MI, who were referred to our hospital from 1997 to 1999, presenting typical chest pain, ST-segment elevation in at least two contiguous leads, and diagnostic serial changes in cardiac enzymes. Patients with atrial fibrillation, mitral stenosis, permanent pacemaker, left bundle branch block, high degree atrioventricular block, coexisting moderate or severe aortic or mitral regurgitation, were not enrolled in the study. Since at the time of patient selection primary interventional revascularisation was less frequent in our hospital, we chose to exclude from the study those who underwent emergency percutaneous transluminal coronary angioplasty or coronary artery bypass graft during hospitalisation. Patients who participated gave written consent and the study protocol was approved by the Hospital Ethics Committee (Red Cross Hospital, Athens), according to the Helsinki Declaration.

### Echocardiography

A complete M-mode and two-dimensional echocardi-

ogram, and Doppler ultrasound examination, were performed  $8.07 \pm 0.96$  days post MI, by two observers who were unaware of the study protocol, with an ATL-UM9 ultrasound unit, using a 2.5 MHz phased array transducer. LV filling was assessed with pulsed-wave Doppler echocardiography. Measurements were obtained with the transducer in the apical four-chamber view, and the Doppler beam aligned as perpendicular as possible to the plane of the mitral annulus. To obtain mitral flow velocities, the pulsed Doppler sample volume was placed between the tips of the mitral leaflets during diastole. Care was taken with this manoeuvre because the sample volume position is critical, as different locations may significantly influence the flow velocity curve.<sup>17</sup> The peak mitral inflow E and A wave velocities, E/A ratio, Edt and Adt were assessed. Adt was calculated as the time between peak A velocity and the upper deceleration slope extrapolated to zero baseline. In addition, from the apical five-chamber view with the pulsed-wave Doppler sample volume positioned in the LV outflow tract, where both mitral inflow and aortic outflow patterns are recordable, we measured the LV isovolumic relaxation time (IRT: the interval between the end of the aortic flow and the onset of the mitral inflow).<sup>18</sup> Patients with an E/A ratio  $>2$  and Edt  $<150$  ms were considered to have a restrictive LV filling pattern, while patients with E/A ratio  $<0.7$  and Edt  $>250$  ms, as well as IRT  $>105$  ms, were considered to have an impaired relaxation LV filling pattern.<sup>18,19</sup> The conventional Doppler parameters of transmitral flow velocity, as well as Adt, were calculated at the end of expiration from an average of 5 consecutive cycles. All the subjects were in fasting condition and had not received their morning medication.

### Other echocardiographic measurements

With the patient in the left lateral decubitus position, we used the parasternal long-axis view at the mid-left ventricular level and the M-mode to assess LV end-diastolic diameter. The anteroposterior diameter of the left atrium (LA) was measured at end-systole from the leading edge of the posterior aortic wall to the leading edge of the posterior LA wall on M-mode echocardiography. LV ejection fraction was assessed qualitatively by two-dimensional echocardiography.<sup>20</sup>

### Follow up

Study participants were followed as outpatients at 12-month intervals for a mean period of 44.7 months.

Clinic and hospital records, written correspondence and telephone contacts were used for data collection. During the follow-up period contact was lost with 5 patients; thus, 105 patients were finally included in our study population. For the present analysis the development of congestive heart failure (based on the presence of at least two of the following criteria: bibasilar pulmonary rales, dyspnoea, a third heart sound or radiographic evidence of pulmonary congestion), or cardiac death after hospitalisation were considered as end points. The cause of death was determined from hospital documentation, information from attending physicians and death certificates. Cardiac death was defined as death due to a myocardial infarction, heart failure or documented sudden cardiac death.

### Statistical analysis

Continuous variables are summarised as mean  $\pm$  standard deviation (SD). Categorical variables are expressed as number of observations followed by percentages (%). Statistical analysis was performed using Statistica 6.1 for Windows.

Based on our previous findings that Adt behaviour resembles that of Edt, and that extreme values of Adt detect patients with restrictive physiology or impaired relaxation,<sup>12</sup> we divided our patients into three groups according to Adt duration: group 1 with Adt  $\leq$  70 ms, group 2 with 70 ms < Adt < 115 ms, and group 3 with Adt  $\geq$  115ms.

The  $\chi^2$ -test was used to compare qualitative characteristics. Between-group differences for numerical variables were tested using one-way analysis of variance followed by the Scheffe test for multiple comparisons.

Kaplan-Meier curves were plotted to depict event-free (cardiac death or congestive heart failure) survival for the three groups. Differences between the groups were tested using an extension of Gehan's generalised Wilcoxon test. When both events occurred in the same individual, the time of evolution of heart failure was used for the Kaplan-Meier plot. Univariate and multivariate Cox proportional hazards models were used to test unadjusted and adjusted associations of Adt classification and other LV filling parameters with the development of death or congestive heart failure during follow up. Clinical characteristics selected for multivariate analysis were age, sex, anterior wall MI, presence of arterial hypertension, systolic blood pressure <90 mmHg during echocardiography assessment, treatment with angiotensin con-

verting enzyme-inhibitors (ACE-I), thrombolytic therapy, and Killip class >1 during the acute phase of MI. Echocardiographic/Doppler variables included LV ejection fraction, E/A ratio >2 and Edt <150 ms as indices of restrictive filling,<sup>18,19</sup> IRT >105 ms as a marker of impaired relaxation,<sup>18,19</sup> and Adt classification. Variables that reached levels of significance  $\leq$ 0.20 during univariate analysis were included in the multivariate analysis.

## Results

### Patient characteristics

The clinical and echocardiographic/Doppler characteristics of the study population are summarised in Table 1. Table 2 presents differences in echocardiographic/Doppler characteristics and event rates be-

**Table 1.** Baseline characteristics of the patients (n=105).

<i>(a) Clinical data: mean <math>\pm</math> SD, or n (%).</i>	
Age (yrs)	60 $\pm$ 10
Males	77 (73)
Smoking	68 (65)
Hypertension	48 (46)
Diabetes	14 (13)
Thrombolysis	59 (56)
ACE inhibitors	63 (60)
b-blockers	70 (67)
Ca <sup>2+</sup> -blockers	9 (9)
Nitrates	25 (24)
Antiplatelets	105 (100)
Lipid lowering	51 (49)
Anterior MI	45 (43)
Inferior MI	60 (57)
Heart rate (bpm)	73 $\pm$ 13
Systolic BP (mmHg)	115 $\pm$ 15
Killip classification >1	11 (10)
<i>(b) Echocardiographic/Doppler findings: mean <math>\pm</math> SD</i>	
LVDd (cm)	5 $\pm$ 0.6
Left atrium (cm)	4 $\pm$ 0.4
Ejection fraction (%)	52 $\pm$ 13
E wave (cm/s)	60 $\pm$ 20
A wave (cm/s)	70 $\pm$ 20
E/A ratio	1 $\pm$ 0.6
Edt (ms)	225 $\pm$ 61
Adt (ms)	100 $\pm$ 21
IRT (ms)	127 $\pm$ 33

A – peak transmitral flow velocity at atrial systole; ACE – angiotensin converting enzyme; Adt – deceleration time of late transmitral diastole; BP – blood pressure; E – peak transmitral flow velocity during early diastole; Edt – deceleration time of early diastole; IRT – isovolumic relaxation time; LVDd – left ventricular end diastolic-diameter; MI – myocardial infarction.

**Table 2.** Echocardiographic/Doppler characteristics and event rates according to Adt classification groups.

	Adt ≤70 ms n=11	70 ms < Adt <115 ms n=56	Adt ≥115 ms n=38	ANOVA (or $\chi^2$ ) p
LVDd (cm)	5.6 ± 0.4*	5 ± 0.6	4.8 ± 0.6 <sup>†</sup>	<0.001
Left atrium (cm)	4.2 ± 0.4	4 ± 0.4	3.9 ± 0.5	0.18
Ejection fraction (%)	40 ± 14*	57 ± 11	49 ± 12 <sup>‡</sup>	<0.001
E/A ratio	2.3 ± 0.5*	1.1 ± 0.4	0.6 ± 0.1 <sup>†‡</sup>	<0.001
Edt (ms)	128 ± 19*	210 ± 37	276 ± 52 <sup>†‡</sup>	<0.001
Adt (ms)	64 ± 5*	92 ± 9	123 ± 8 <sup>†‡</sup>	<0.001
IRT (ms)	89 ± 24*	120 ± 25	149 ± 31 <sup>†‡</sup>	<0.001
Restrictive filling pattern, n (%)	7 (64)*	0 (0)	0 (0) <sup>†</sup>	<0.001
Impaired relaxation pattern, n (%)	0 (0)	0 (0)	22 (58) <sup>†‡</sup>	<0.001
Normal/near to normal filling, n (%)	4 (36)*	56 (100)	16 (42) <sup>‡</sup>	<0.001
Number of patients with events, n (%)	6 (55)	2 (3.6)	7 (18)	<0.001
Death	4 (36)*	2 (3.6)	3 (7.9)	0.002
Heart failure	4 (36)*	0 (0)	6 (16) <sup>‡</sup>	<0.001
Revascularisations (PTCA & CABG)	1 (9)	13 (23)	13 (34)	0.20

CABG – coronary artery bypass grafting; PTCA – percutaneous transluminal coronary angioplasty; other abbreviations as in table 1.

\* p<0.05 group 1 vs. group 2, <sup>†</sup>p<0.05 group 1 vs. group 3, <sup>‡</sup>p<0.05 group 3 vs. group 2.

tween the patient groups formed according to Adt classification. In detail, 7/11 (64%) patients of the group with Adt ≤70 ms presented characteristics of restrictive physiology, 22/38 (58%) patients of the group with Adt >115 ms had characteristics of impaired relaxation, while 56/56 (100%) patients of the group with 70 ms < Adt < 115 ms had a normal or near to normal LV filling pattern.<sup>18,19</sup> From the above findings it is clear that the majority of patients with low values of Adt have a restrictive physiology, while high values are associated with an impaired relaxation LV filling pattern. Finally, the ejection fraction of patients in groups 1 and 3 was significantly lower than that of patients in group 2, while the ejection fraction in group 3 was higher than that in group 1, though the difference did not reach statistical significance.

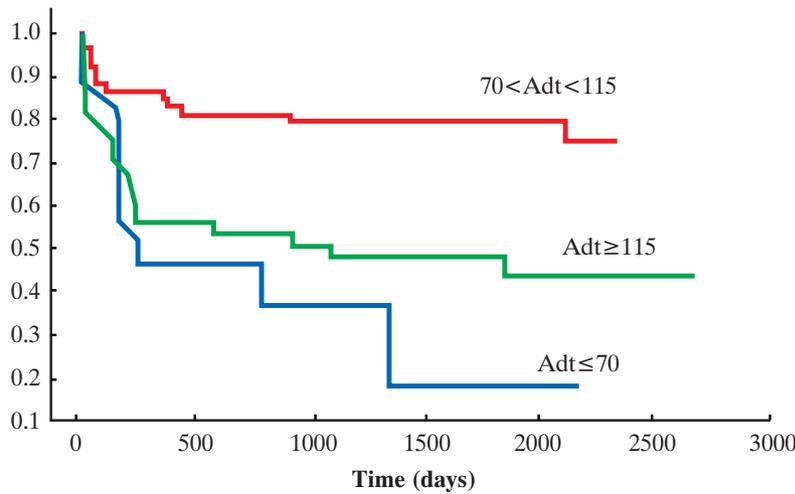
### Outcome

Patients were followed up for a mean of 44.7 months. During this period there were 15 (14%) cardiac events, 9 (9%) cardiac deaths (5 patients from sudden death, 4 from progressive heart failure), and 10 (9%) cases with congestive heart failure (Table 2). Because of the 4 deaths from progressive heart failure, total events (n=15) were less than the sum of deaths plus heart failures n=19). Cardiac events were more frequent in acute MI survivors with Adt ≤70 ms (restrictive filling pattern) and in those with Adt ≥115 ms (impaired relaxation

filling pattern) than in patients with 70 ms < Adt < 115 ms (normal or near to normal filling pattern) (Table 2). Kaplan-Meier survival curves indicated that patients with Adt ≤70 ms or Adt ≥115 ms were more likely to experience cardiac events and had a significantly shorter event-free survival period ( $\chi^2=17.77$  with 2 degrees of freedom, p=0.0017) (Figure 1). Median event-free survival was 237 days for group 1, 1975 days for group 2, and 1012 days for group 3 (p=0.0017). Congestive heart failure occurred more frequently in groups 1 and 3 than in group 2, while the frequency of deaths was higher only in group 1 in comparison to group 2. The 3 groups did not differ significantly with regard to revascularisation procedures during patients' follow up.

### Cox proportional hazards model analysis

Univariate regression analysis identified Adt ≤70 ms, Adt ≥115 ms, restrictive LV filling pattern, anterior wall MI, ejection fraction <50%, age, the use of ACE-I, and Killip class >1 on hospital admission as significant predictors of future outcome (Table 3). The presence of systolic blood pressure <90 mmHg, thrombolytic therapy and Adt ≥115 ms had borderline associations with the presence of the pre-specified adverse events, but as the level of significance was below 0.20 they were tested for independence in the multivariate model. Multivariate Cox regression



**Figure 1.** Cumulative proportion surviving in groups of patients with regard to Adt values ( $\chi^2 = 17.77$  with 2 degrees of freedom,  $p=0.0017$ ).

analysis identified  $Adt \leq 70$  ms,  $Adt \geq 115$  ms, restrictive LV filling pattern, anterior wall MI, LV ejection fraction  $<50\%$ , and age as independent predictors of the development of congestive heart failure or cardiac death during follow-up. In addition, the use of ACE-I independently identified patients with lower risk (relative ratio 0.23) for future adverse events.

**Discussion**

To the best of our knowledge this is the first prospective study investigating the prognostic value of Adt. The main finding of the present echocardiographic project was that Adt identified patients with increased ad-

verse events following an acute MI. We found that low Adt values ( $\leq 70$  ms) were associated with the development of congestive heart failure and cardiac death after hospitalisation, whereas high Adt values ( $\geq 115$  ms) were associated only with heart failure. In contrast, patients with intermediate values of Adt ( $70 \text{ ms} < Adt < 115 \text{ ms}$ ) experienced significantly fewer cardiac events.

**Prognostic implications of LV diastolic filling patterns**

*Restrictive filling*

Several studies<sup>3,13,14</sup> have shown that Doppler-derived

**Table 3.** Univariate and multivariate Cox model of conventional diastolic Doppler-variables and Adt classification in prediction of cardiac events.

	Univariate		Multivariate	
	RR (95%CI)	p	RR (95%CI)	p
Age	1.08 (1.01-1.15)	0.02	1.10 (1.01-1.21)	0.04
Male sex	1.44 (0.49-4.23)	0.5		
Ejection fraction $<50\%$	0.96 (0.93-0.99)	0.03	0.94 (0.89-0.99)	0.03
Anterior MI	3.29 (1.25-8.65)	0.02	6.78 (1.37-33.61)	0.02
Arterial hypertension	1.39 (0.56-3.42)	0.47		
SBP $<90$ mmHg	3.56 (0.82-15.43)	0.09	4.47 (0.81-24.86)	0.08
ACE inhibitors	0.24 (0.09-0.65)	0.005	0.23 (0.08-0.70)	0.009
Thrombolysis	0.41 (0.16-1.05)	0.06	0.66 (0.21-2.03)	0.47
Killip $>1$	2.99 (1.14-7.88)	0.02	1.48 (0.35-15.17)	0.59
Restrictive pattern	4.71 (1.55-14.33)	0.006	5.16 (1.76-96.03)	0.003
IRT	1.66 (0.65-4.22)	0.29		
Adt $\leq 70$ ms	11.18 (4.38-28.53)	0.0000	7.29 (1.46-36.39)	0.002
Adt $\geq 115$ ms	3.46 (0.85-14)	0.08	3.69 (1.65-8.23)	0.02

RR relative risk; CI confidence interval; other abbreviations as in Table 1.

diastolic filling variables (in particular, E/A ratio  $>2$  and short mitral E-wave deceleration time) are important predictors of cardiac death in patients with various cardiac diseases. Restrictive LV filling pattern has been reported as a powerful independent predictor of cardiac death<sup>4,5</sup> or heart failure<sup>2,5</sup> and has been related to progressive LV dilatation<sup>6,7</sup> after an acute MI. Furthermore, a restrictive pattern has been demonstrated to be more common in patients with a large infarction and low ejection fraction.<sup>5,21,22</sup> Since the majority of patients with Adt values  $\leq 70$  ms had a restrictive physiology, our findings seem consistent with previous studies regarding the risk for development of congestive heart failure and cardiac death after MI. Moreover, patients of this group had moderate LV systolic dysfunction, manifested by a relatively low ejection fraction ( $40 \pm 14\%$ ). The latter finding, with the contribution of Adt, documents once again that restrictive physiology identifies a subgroup of patients at very high risk of cardiac death or heart failure within the group of patients with moderate to severe LV systolic dysfunction.

#### *Impaired relaxation pattern*

The prognostic value of an impaired relaxation LV filling pattern has not been so well clarified as has that of a restrictive LV filling pattern. Several studies<sup>15,23,24</sup> have reported that markers of impaired relaxation, such as low E/A ratio and prolonged mitral E-wave deceleration time or isovolumic relaxation time, identified patients with increased mortality,<sup>15</sup> heart failure<sup>23</sup> and cardiovascular risk<sup>24</sup> in several settings. On the other hand, other recent studies have shown a rather weak correlation between this type of LV diastolic dysfunction and New York Heart Association class or cardiac mortality,<sup>16,25</sup> especially in patients with satisfactory LV systolic function.<sup>16</sup> In the setting of MI, it has been demonstrated that patients with impaired relaxation had a more favourable outcome in comparison with patients presenting a restrictive physiology.<sup>5,6,25</sup> These studies<sup>5,6</sup> reported that an impaired relaxation LV filling pattern was more closely associated with the post-infarction LV remodelling process (compensatory hypertrophy and LV dilatation) leading to symptoms of heart failure,<sup>5</sup> and seemed to be weakly related to cardiac death.<sup>5,6</sup> Furthermore, the impaired relaxation LV filling pattern is more common in limited infarction with preserved ejection fraction.<sup>5,20,22</sup> In agreement with the existing evidence concerning patients with impaired relaxation, Adt  $\geq 115$  ms detect-

ed those developing congestive heart failure but not those with cardiac death. In addition, our patients who had an impaired relaxation LV filling pattern presented preserved systolic function (ejection fraction  $49 \pm 12\%$ ), a finding which is also in accordance with previous studies.

#### *Prognostic value of Adt*

The active atrial contribution to late filling, against a less compliant ventricle (in comparison with the early passive filling), could provide Adt with prognostic ability. In this study, intermediate values of Adt ( $70$  ms  $<$  Adt  $< 115$  ms) were detected in patients presenting normal or near to normal LV diastolic function and were associated with those experiencing significantly fewer cardiac events in comparison with the patients of the other two groups, a finding also consistent with previous studies of MI patients.<sup>5,6</sup> In Cox regression multivariate analysis, Adt classification (Adt  $\leq 70$  ms or  $\geq 115$  ms) and a restrictive LV filling pattern were reported as the most potent independent predictors of future adverse outcome. Recent studies showed that the duration of Adt is an important index for the estimation of LV end-diastolic pressure.<sup>26,27</sup> It seems that the material contribution of Adt to the duration of the A wave of transmitral flow, as well as its ability to detect patients with either restrictive physiology or impaired relaxation, provides Adt with prognostic accuracy.

#### *Limitations*

For obvious reasons, Adt is not applicable in patients with mitral stenosis, atrial fibrillation, atrioventricular conductive disorders and an abnormally short PR interval; therefore, those conditions were excluded. Furthermore, the possibility of left atrial mechanical failure<sup>28</sup> in the patients with Adt  $\leq 70$  ms (restrictive filling pattern), could have affected the reliable interpretation of mitral A wave pattern. However, the relatively small left atrial and LV dimension, as well as the satisfactory ejection fraction are indicative of effective atrial contractility.<sup>29</sup>

Invasive procedures were not performed routinely in this study. However, the echocardiographic Doppler measurements that were used, Adt included, have previously been shown to have a close relation to invasive measures of pressure.<sup>10,11,17,30</sup>

As an additional potential limitation, patients were examined only once, at baseline; serial determinations

could have provided additional prognostic information. In fact, it is well known that the LV remodelling process continues for a long time late after infarction<sup>31</sup> and that LV filling patterns may change during the course of the disease, because of deterioration or improvement of cardiac function or as a consequence of therapeutic interventions.<sup>32</sup> Indeed, these changes of classic diastolic Doppler-parameters during remodelling after MI have been studied previously by other investigators.<sup>5,6,21</sup> In a previous study,<sup>12</sup> we showed that Adt behaves similarly to mitral E-wave deceleration time during the early phase of MI; however, the variation of Adt during the late phase of MI has not yet been studied and seems attractive for future research.

The majority of our patients showed an LV filling pattern characterised by an E/A ratio >1 or <2 (group 2), which may really be normal or pseudonormal. Application of novel techniques, such as tissue Doppler imaging and velocity flow propagation, could possibly detect patients with pseudonormal physiology. However, the prolonged isovolumic relaxation time of these patients, as well as the preserved ejection fraction, are indices supportive of non-increased filling pressures and normal LV filling pattern.<sup>30</sup> Moreover, 4/11 (36%) patients of the group with Adt ≤70 ms and 16/38 (42%) patients of the group with Adt ≥115 ms showed a normal or near to normal LV filling pattern. The use of the above techniques could possibly add potency in the identification of patients with restrictive physiology or impaired relaxation, a fact that would not affect our study results.

Finally, at the time of the echocardiographic evaluation all patients were hospitalised, were in a clinically stable condition, and were receiving optimal medical therapy. Consequently, measurement variations caused by fortuitous changes in loading conditions were minimised, thus enhancing the prognostic power of LV filling patterns. However, data regarding the effect of loading conditions on Adt are still lacking.

## Conclusions

Despite the above limitations, we may conclude that the easily obtainable Adt seems to be a strong and independent predictor of congestive heart failure and cardiac death following MI. A shortened Adt ≤70 ms is associated with higher rates of cardiac death or heart failure, while a prolonged Adt ≥115 ms is associated only with heart failure.

## References

1. Pheffer A, Braunwald E, Moya L: Effect of captopril on mortality and morbidity in patients with LV dysfunction after MI: results of the Survival And Ventricular Enlargement trial. The SAVE investigators. *N Engl J Med* 1992; 327: 669-677.
2. Oh J, Ding Z, Gersh B, et al: Restrictive LV diastolic filling identifies patients with heart failure after acute MI. *J Am Soc Echocardiogr* 1992; 5: 497-503.
3. Xie G, Berk M, Smith M, Gurley J, De Maria A: Prognostic value of Doppler transmitral flow patterns in patients with CHF. *J Am Coll Cardiol* 1994; 24: 132-139.
4. Nijland F, Kamp O, Karreman A, et al: Prognostic implications of restrictive left ventricular filling in acute myocardial infarction: a serial Doppler echocardiographic study. *J Am Coll Cardiol* 1997; 30: 1618-1624.
5. Poulsen S, Jensen S, Egstrup K: Longitudinal changes and prognostic implications of left ventricular diastolic function in first acute myocardial infarction. *Am Heart J* 1999; 137: 910-918.
6. Moller J, Sondergaard E, Poulsen S, et al: Pseudonormal and restrictive filling patterns predict left ventricular dilatation and cardiac death after a first myocardial infarction: a serial color M-mode Doppler echocardiographic study. *J Am Coll Cardiol* 2000; 36: 1841-1846.
7. Cerisano G, Bolognese L, Carabba N, et al: Doppler derived mitral deceleration time. An early strong predictor of left ventricular remodeling after reperfused anterior acute myocardial infarction. *Circulation* 1999; 99: 230-236.
8. Gonzalez-Vilchez F, Ares M, Ayuela J, et al: Combined use of pulsed and color M-mode Doppler echocardiography for the estimation of pulmonary capillary wedge pressure: An empirical approach based on an analytical relation. *J Am Coll Cardiol* 1999; 34: 515-523.
9. Ommen S, Nishimura R, Appleton C, et al: Clinical utility of Doppler echocardiography and tissue Doppler imaging in the estimation of left ventricular filling pressures. A comparative simultaneous Doppler-catheterization study. *Circulation* 2000; 102: 1788-1794.
10. Tenenbaum A, Motro M, Hod H, et al: Shortened Doppler-derived mitral A-wave deceleration time: an important predictor of elevated left ventricular filling pressure. *J Am Coll Cardiol* 1996; 27: 700-705.
11. Paraskevaidis I, Tsiapras D, Karavolias G, et al: Doppler-derived left ventricular end-diastolic pressure prediction model using the combined analysis of mitral and pulmonary A waves in patients with coronary artery disease and preserved left ventricular systolic function. *Am J Cardiol* 2002; 90: 720-724.
12. Nearchou N, Karatzis E, Lolaka M, et al: Mitral A-wave deceleration time. A marker of left ventricular diastolic dysfunction following acute myocardial infarction? *Int J Cardiol* 2006; 109: 129-131.
13. Klein A, Hatle L, Taliere C, et al: Prognostic significance of Doppler measures of diastolic function in cardiac amyloidosis: a Doppler echocardiography study. *Circulation* 1991; 83: 808-816.
14. Seacord L, Miller L, Pennington D, et al: Reversal of constrictive/restrictive physiology with treatment of allograft rejection. *Am Heart J* 1990; 120: 455-459.
15. Vasan R, Larson M, Benjamin E, et al: Congestive heart failure in subjects with normal versus reduced left ventricular ejection fraction: prevalence and mortality in a population-based cohort. *J Am Coll Cardiol* 1999; 33: 1948-1955.

16. Nielsen W, Sajedieh A, Petersen F, et al: Value of left ventricular filling parameters to predict mortality and functional class in patients with heart disease from the community. *Eur J Echocardiography* 2005; 6: 85-91.
17. Giannuzzi P, Imparato A, Temporelli P, et al: Doppler-derived mitral deceleration time of early filling as a strong predictor of pulmonary capillary wedge pressure in postinfarction patients with left ventricular systolic dysfunction. *J Am Coll Cardiol* 1994; 23: 1630-1637.
18. Rakowski H, Appleton C, Chan K, et al: Canadian consensus recommendations for the measurement and reporting of diastolic dysfunction by echocardiography. *J Am Soc echocardiogr* 1996; 9: 736-760.
19. European Study Group on Diastolic Heart Failure: How to diagnose diastolic heart failure? *Eur Heart J* 1998; 19: 990-1003.
20. Quinones M, Waggoner A, Reduto L, et al: A new, simplified and accurate method for determining ejection fraction with two-dimensional echocardiography. *Circulation* 1981; 64: 744-753.
21. Pipilis A, Meyer T, Ormerod O, et al: Early and late changes in left ventricular filling after acute myocardial infarction and the effect of infarct size. *Am J Cardiol* 1992; 70: 1397-1401.
22. Algom M, Schlesinger Z: Serial changes in left ventricular diastolic indexes derived from Doppler echocardiography after anterior wall acute myocardial infarction. *Am J Cardiol* 1995; 75: 1272-1273.
23. Aurigemma G, Gottdiener J, Shemanski L, et al: Predictive value of systolic and diastolic function for incident congestive heart failure in the elderly: the cardiovascular health study. *J Am Coll Cardiol* 2001; 37: 1042-1048.
24. Schillaci G, Pasqualini L, Verdecchia P, et al: Prognostic significance of left ventricular diastolic dysfunction in essential hypertension. *J Am Coll Cardiol* 2002; 39: 2005-2011.
25. Bella J, Palmieri V, Roman M, et al: Mitral ratio of peak early to late diastolic filling velocity as a predictor of mortality in middle-aged and elderly adults: the Strong Heart Study. *Circulation* 2002; 105: 1928-1933.
26. Yamamoto K, Nishimura RA, Burnett JC Jr, et al: Assessment of left ventricular end-diastolic pressure by Doppler echocardiography: contribution of duration of pulmonary venous versus mitral flow velocity curves at atrial contraction. *J Am Soc Echocardiogr* 1997; 10: 52-59.
27. Appleton CP: Hemodynamic determinants of Doppler pulmonary venous flow velocity components: new insights from studies in lightly sedated normal dogs. *J Am Coll Cardiol* 1997; 30: 1562-1574.
28. Wang K, Gibson D: Non-invasive detection of left atrial mechanical failure in patients with left ventricular disease. *Br Heart J* 1995; 74: 536-540.
29. Appleton C, Galloway J, Gonzalez M, et al: Estimation of left ventricular filling pressures using two-dimensional and Doppler echocardiography in adult cardiac patients: additional value of analysing left atrial size, left atrial ejection fraction and the difference in the duration of pulmonary venous and mitral flow velocities at atrial contraction. *J Am Coll Cardiol* 1993; 22: 1972-1982.
30. Yamamoto K, Nishimura R, Chaliki H, et al: Determination of left ventricular filling pressure by Doppler echocardiography in patients with coronary artery disease: Critical role of left ventricular systolic function. *J Am Coll Cardiol* 1997; 30: 1819-1826.
31. Kupper W, Bleifeld W, Hanrath P, et al: Left ventricular hemodynamics and function in acute myocardial infarction: studies during the acute phase, convalescence and late recovery. *Am J Cardiol* 1977; 40: 900-905.
32. Kono T, Sabbah H, Rosman H, et al: Left atrial contribution to ventricular filling during the course of evolving heart failure. *Circulation* 1992; 86: 1317-1322.