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Ratio of Left Ventricular Peak E-Wave Velocity to Flow Propagation Velocity Assessed by Color M-mode Doppler Echocardiography in First Myocardial Infarction

Prognostic and Clinical Implications

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OBJECTIVES To determine the ability of the ratio of peak E-wave velocity to flow propagation velocity (E/Vp) measured with color M-mode Doppler echocardiography to predict in-hospital heart failure and cardiac mortality in an unselected consecutive population with first myocardial infarction (MI).

BACKGROUND Several experimental studies indicate color M-mode echocardiography to be a valuable tool in the evaluation of diastolic function, but data regarding the clinical value are lacking.

METHODS Echocardiography was performed within 24 h of arrival at the coronary care unit in 110 consecutive patients with first MI. Highest Killip class was determined during hospitalization. Patients were divided into groups according to E/Vp <1.5 and ≥ 1.5.

RESULTS During hospitalization 53 patients were in Killip class ≥II. In patients with E/Vp ≥ 1.5, Killip class was significantly higher compared with patients with E/Vp <1.5 ($p < 0.0001$). Multivariate logistic regression analysis identified E/Vp ≥ 1.5 to be the single best predictor of in-hospital clinical heart failure when compared with age, heart rate, E-wave deceleration time (Dt), left ventricular (LV) ejection fraction, wall motion index, enzymatic infarct size and Q-wave MI. At day 35 survival in patients with E/Vp <1.5 was 98%, while for patients with E/Vp ≥ 1.5, it was 58% ($p < 0.0001$). Cox proportional hazards model identified Dt <140 ms, E/Vp ≥ 1.5 and age to be independent predictors of cardiac death, with Dt $<$ 140 ms being superior to age and E/Vp.

CONCLUSIONS In the acute phase of MI, E/Vp ≥ 1.5 measured with color M-mode echocardiography is a strong predictor of in-hospital heart failure. Furthermore, E/Vp is superior to systolic measurements in predicting 35 day survival although Dt <140 ms is the most powerful predictor of cardiac death. (J Am Coll Cardiol 2000;35:363–70) © 2000 by the American College of Cardiology

The importance of left ventricular (LV) systolic dysfunction as a predictor of mortality and morbidity after myocardial infarction (MI) is well known (1,2). In MI, Doppler echocardiography can be used to determine LV diastolic function (3,4), and a restrictive transmitral flow pattern has been related to the development of congestive heart failure (5–7) and to increased mortality (8). In patients with various etiologies of LV systolic dysfunction, restrictive filling has also proven to be an independent predictor of adverse outcome (9–14). The limitations of Doppler flow patterns are related to the difficulties in distinguishing between the normal and the pseudonormal filling pattern and to the influence of heart rate, age and loading conditions upon the measurements (15,16).

Recently, color M-mode Doppler echocardiography has been shown to provide information about LV diastolic function (17–24). The flow propagation velocity of early transmitral flow (Vp) determined from color M-mode recordings has been shown to be inversely correlated with the time constant of isovolumetric relaxation (tau) (17–19). The main determinants of standard pulsed Doppler peak E-wave velocity (E) are simplified left atrial pressure and tau; therefore, a combination of E and Vp may, in theory, estimate LV end diastolic pressure (LVEDP). This thesis

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Abbreviations and Acronyms

Dt	=	E-wave deceleration time
E	=	peak E-wave velocity
E/Vp	=	the ratio of E to Vp
LV	=	left ventricular
LVEDP	=	left ventricular end diastolic pressure
MI	=	myocardial infarction
tau	=	time constant of isovolumetric relaxation
Vp	=	flow propagation velocity
WMI	=	wall motion index

has been investigated in patients in sinus rhythm (22) and in patients in atrial fibrillation (23). In both studies, a strong correlation between the ratio of E to Vp (E/Vp) and LVEDP was shown. In these studies E/Vp >1.5 was found highly predictive of elevated LVEDP. Furthermore, preliminary data suggest that Vp is not affected significantly by preload (18,24). Therefore it may provide a simple tool to identify patients with pseudonormal filling pattern. The value of E/Vp in the outcome stratification after MI has not previously been reported.

The objective of this investigation was, therefore, to assess the ability of E/Vp to predict in-hospital heart failure in an unselected consecutive population with first MI and to assess the short-term prognostic value of E/Vp on cardiac mortality.

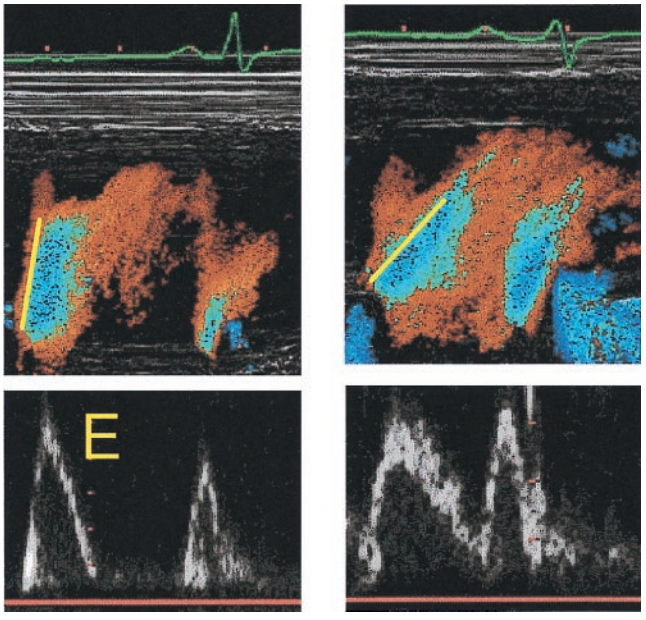

Figure 1. Flow propagation velocity (Vp) was determined as the slope **(yellow line)** of the isovelocity line from the mitral plane to 4 cm apically into the left ventricle. **Top left:** Color M-mode recording of LV inflow from a normal subject. **Bottom left:** Pulsed wave Doppler signal of normal transmitral flow. E/Vp in this control was 0.99. **Top right:** Color M-mode recording from a patient with anterior MI and decreased Vp but normal appearing pulsed wave Doppler signal of LV mitral inflow **(Bottom right)**. E/Vp in this patient was 2.1. E: peak E-wave velocity.

METHODS

The study population consisted of 112 consecutive patients admitted to the coronary care unit at Svendborg Hospital, Denmark, with first MI diagnosed by at least two of the following criteria: 1) characteristic chest pain, 2) electrocardiographic signs of MI, 3) transient elevation of creatine kinase >210 IU/liter and creatine kinase MB >20 IU/liter. One patient was excluded due to aortic stenosis and one patient due to dementia, leaving a total of 110 patients (98%). Normal values of Vp and E/Vp were obtained prospectively in 30 healthy volunteers with no history of cardiovascular diseases who demonstrated normal physical examination, normal resting ECG and normal Doppler echocardiography. The protocol was approved by the scientific ethical committee for Fyn's County, and all enrolled patients gave written, informed consent.

Doppler echocardiography. Echocardiography was performed within 24 h of arrival to the coronary care unit. Follow-up was done 35 (32–37) days after MI. Echocardiography was performed on a Hewlett Packard (Sonos Company, Andover, Massachusetts) 5500 with a 2.5 MHz transducer. Echocardiograms were stored digitally, and analysis were done blinded for all clinical data. Measurements of Vp were done separately from two-dimensional and pulsed Doppler measurements. For patients in sinus rhythm, five consecutive beats were measured and averaged for each Doppler variable, and for patients in atrial fibrillation, 10 consecutive beats were measured (23). If present, severity of mitral regurgitation was graded by calculating the fraction of regurgitation by quantitative Doppler echocardiography (25).

Based on visual impression of regional wall motion, a wall motion index (WMI) was obtained semiquantitatively using a 16-segment model of the LV as proposed by the American Society of Echocardiography (26). Left ventricular volumes and ejection fraction were estimated using Simpson's modified biplane method (26). Left ventricular volumes were corrected for body surface area.

Pulsed Doppler measurements were obtained with the transducer in the apical four chamber view. The Doppler beam was aligned as perpendicular as possible to the plane of the mitral annulus. To obtain mitral flow velocity, a 1 to 2 mm Doppler sample volume was placed between the tips of mitral leaflets during diastole.

Color M-mode echocardiography was done in the apical four chamber view with the cursor aligned parallel with LV inflow. Adjustments were made to obtain the longest column of flow from the mitral annulus to the apex of the LV. The M-mode cursor was positioned through the center of inflow, avoiding boundary regions. Flow propagation velocity was measured as the slope of the first color aliasing velocity (45 cm/s) from the mitral annulus in early diastole to 4 cm distally into the LV cavity (Fig. 1). In patients with

Table 1. Baseline Demographic and Clinical Variables

	E/Vp < 1.5 n = 58	E/Vp ≥ 1.5 n = 52	p Value
Age (yr)	63 ± 12	73 ± 11	0.001
History of ischemic heart disease	25 (43%)	30 (58%)	NS
Current smoker	34 (58%)	28 (54%)	NS
S-cholesterol (mmol/liter)	5.7 ± 0.9	6.2 ± 1.0	NS
Q-wave MI	18 (31%)	24 (48%)	NS
Anterior MI	24 (41%)	24 (46%)	NS
Reperfusion therapy	35 (60%)	21 (40%)	NS
Patency of infarct related artery	31 (88%)	14 (67%)	NS
Rescue angioplasty	3 (5%)	4 (8%)	NS
Peak creatine kinase MB (IU/liter)	81 ± 65	122 ± 77	NS
Sinus rhythm	57 (98%)	49 (94%)	NS
Atrial fibrillation	1 (2%)	3 (6%)	NS
Heart rate at admission (min^{-1})	77 ± 13	81 ± 19	NS
Systolic blood pressure at admission (mm Hg)	139 ± 28	124 ± 29	0.02

Continuous data presented as mean ± SD.
MI = myocardial infarction.

low peak E-wave velocity where no color aliasing was seen, baseline shift was adjusted to aliase at about 75% of the peak E-wave velocity.

Based on the ratio E/Vp, patients were divided into two groups according to E/Vp <1.5 and E/Vp ≥1.5, suggestive of elevated LVEDP (22,23).

During hospitalization, Killip class was determined on a daily basis; the highest Killip class recorded was entered in the statistical analysis. If patients were in Killip class ≥II, a chest X-ray was performed. All chest X-rays were evaluated by radiologists unaware of the echocardiographic findings. Patency of the infarct related artery in patients given reperfusion therapy was considered to be achieved when a decrease of ≥50% from peak ST elevation in ECG 60 min after therapy was seen (27). Rescue angioplasty was considered in all patients with no signs of patency after thrombolysis. Patients with inducible ischemia were referred for coronary arteriography and revascularized accordingly.

Statistics. Continuous data are expressed as mean ± standard deviation. Comparison between groups of discrete variables was performed using the Yate's corrected chi-square test; continuous and normally distributed variables were tested with unpaired Student *t* test with Bonferroni correction. Cumulative survival analysis was performed using Kaplan Meier plots. Statistical difference between subgroups was tested with the log rank test. Stepwise multivariate logistic regression analysis was performed to identify predictors of in-hospital heart failure. Furthermore, echocardiographic variables and clinical variables were compared for their ability to predict mortality by means of the Cox proportional hazards model. Clinical and echocardiographic variables included in the stepwise multivariate logistic regression analysis and the Cox proportional hazards model were selected by univariate analysis. $P < 0.05$ was considered significant. Statistical analysis was performed using SPSS for Windows version 7.0. (SPSS Inc., Chicago, Illinois).

Reproducibility. Fifteen studies were chosen at random for reanalysis of Vp. Reanalyses were done by second observer and first observer at different times. Inter- and intraobserver variability was expressed as mean percent error (absolute difference divided by the average of the two observations).

RESULTS

The average age of the 110 patients was 67 ± 12 years, range 32 to 94 years (56% men, 44% women). One hundred six patients (96%) were in sinus rhythm, and four patients (4%) were in atrial fibrillation. Echocardiography was performed at a mean of 6 h (range 0 to 17 h) after arrival at the coronary care unit. Mean Vp at baseline was 53 ± 23 cm/s, and the ratio E/Vp was 1.7 ± 0.9. In 58 patients (53%) E/Vp was <1.5, and in 52 patients (47%), E/Vp was ≥1.5. There were no significant correlations between timing of echocardiography and Vp ($r = -0.012$, $p = 0.89$) or with E/Vp ($r = -0.11$, $p = 0.24$). Demographic and clinical variables are summarized in Table 1 and echocardiographic variables in Table 2. In 30 controls aged 32 to 83 years, mean Vp was 76 ± 16 cm/s ($p < 0.0001$ compared with MI patients) and mean E/Vp 1.01 ± 0.16 ($p < 0.0001$ compared with MI patients). In no controls was E/Vp found to be ≥1.5 (Table 3). There was no correlation between age of volunteers and E/Vp ($r = -0.05$, $p = 0.81$).

Heart failure. Fifty-three patients (48%) had signs of in-hospital heart failure. The highest Killip class achieved was: in 28 patients (25%), class II; in 15 patients (14%), class III; and in 10 patients (9%), class IV. In 49 patients with in-hospital heart failure (92%), chest X-ray was performed and revealed cardiomegaly (cardiothoracic ratio >0.5) or pulmonary congestion. In four patients chest X-ray was not

Table 2. Baseline Echocardiographic Variables

	E/Vp < 1.5 n = 58	E/Vp ≥ 1.5 n = 52	p Value
Wall motion index	1.32 ± 0.19	1.65 ± 0.34	0.001
Ejection fraction	0.62 ± 0.12	0.45 ± 0.14	0.001
End systolic volume index (ml/m^2)	24 ± 12	41 ± 21	0.001
Flow propagation velocity (cm/s)	68 ± 22	37 ± 11	<0.0001
Peak E-wave velocity (cm/s)	70 ± 28	88 ± 30	NS
Peak A-wave velocity (cm/s)	72 ± 24	71 ± 29	NS
E/A ratio	1.1 ± 0.7	1.6 ± 1.3	NS
Isovolumetric relaxation time (ms)	91 ± 29	85 ± 30	NS
E-wave deceleration time (ms)	218 ± 54	174 ± 70	0.02
Presence of mitral regurgitation	11 (18%)	20 (38%)	NS
fraction of mitral regurgitation	(0.11 ± 0.07)	(0.15 ± 0.11)	

Continuous data presented as mean ± SD.
E = peak E-wave velocity; E/Vp = the ratio of E to Vp; Vp = flow propagation velocity.

performed; all four patients were in overt cardiogenic shock. Patients with E/Vp ≥1.5 were in significantly higher Killip class than patients with E/Vp <1.5 (Fig. 2). Univariate analysis was performed to determine correlates of in-hospital heart failure (Table 4). Variables identified in the univariate analysis to be significantly correlated with in-hospital heart failure were included in a multivariate stepwise logistic regression analysis. In this model, E/Vp proved to be the single best predictor of in-hospital heart failure (Table 4).

Survival. During follow-up of 35 days, 23 patients (21%) died of cardiac causes. Cause of death was: in 8 patients, cardiogenic shock; in 9 patients, sudden death (4 patients from in-hospital ventricular fibrillation); in 2 patients, papillary muscle rupture; in 1 patient, myocardial reinfarction; in 2 patients, postinfarction ventricular septal defect; and in 1 patient, LV free wall rupture. No patients died of noncardiac causes.

In the group with E/Vp <1.5, 57 of 58 patients (98%) were alive at day 35; in the group with E/Vp ≥1.5, 30 of 52 patients (58%) were alive at follow-up. Figure 3 presents Kaplan Meier plots of cumulative survival in patients classified after E/Vp and Dt. Predictors of cardiac death identified by univariate Cox analysis are summarized in Table 5. These variables were entered in a Cox proportional hazards analysis. In the analysis, Dt < 140 ms, E/Vp ≥ 1.5 and age proved to be independent predictors of cardiac death. E-wave deceleration time <140 ms was the single best predictor of cardiac death (Table 5). No systolic variables proved to be independent predictors of outcome.

The data indicate patients with E/Vp <1.5 and nonrestrictive filling (Dt > 140 ms) to have a good prognosis (1 of 58 patients died); patients with nonrestrictive filling but E/Vp ≥1.5 seemed to have an intermediate prognosis (8 patients of 28 died), and patients with restrictive filling and E/Vp ≥1.5 had a poor prognosis (14 patients of 24 died).

Table 3. Demographic and Echocardiographic Variables in Normal Subjects

	n = 30
Age (yr)	63 ± 11
Men/women	17/13
Current smoker (%)	14 (47%)
Systolic blood pressure (mm Hg)	133 ± 16
Heart rate (beats per min)	66 ± 11
Ejection fraction	0.68 ± 0.07
Vp (cm/s)	76 ± 18
E/Vp	1.01 ± 0.16
Peak E-wave velocity (cm/s)	77 ± 20
Peak A-wave velocity (cm/s)	70 ± 16
E/A ratio	1.2 ± 0.4
Isovolumetric relaxation time (ms)	74 ± 11
E-wave deceleration time (ms)	196 ± 29

Continuous data presented as mean ± SD.
E = peak E-wave velocity; E/Vp = the ratio of E to Vp; Vp = flow propagation velocity.

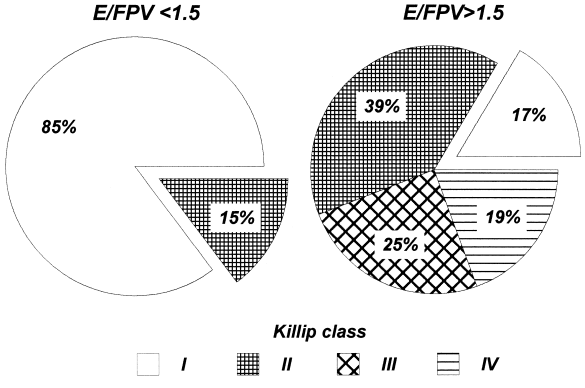

Figure 2. Highest Killip class in patients classified after the ratio of peak E-wave velocity and flow propagation velocity ≥1.5. Killip class in the group with E/Vp ≥1.5 was significantly higher than the group with normal ratio ($p < 0.0001$ Mann-Whitney *U* rank test).

Table 4. Uni- and Multivariate Logistic Regression Analysis for Predictors of In-Hospital Heart Failure

	Wald Chi-Square	p Value	Odds Ratio [95% CI]
Univariate Analysis			
E/Vp ≥ 1.5	48.0	< 0.0001	40.4 (14.9; 109.9)
Age	16.1	0.0001	6.2 (3.1; 9.4)*
Heart rate at admission	15.1	0.0001	5.4 (2.7; 8.3)†
E-wave deceleration time < 140 ms	14.8	0.0001	19.5 (4.3; 88.0)
Vp	14.8	0.0001	4.2 (2.6; 5.7)‡
Wall motion index > 1.7	13.2	0.0003	16.9 (3.1; 39.5)
Ejection fraction < 0.40	12.4	0.0004	15.3 (3.3; 70.1)
Peak creatine kinase MB	11.9	0.0003	1.5 (0.7; 2.4)**
E/A ratio	6.9	0.009	2.2 (1.2; 3.9)
Q-wave MI	5.0	0.03	2.5 (1.1; 5.4)
Systolic blood pressure	3.4	0.06	
Reperfusion therapy	1.7	0.19	
Stepwise Multivariate Logistic Regression Analysis			
E/Vp ≥ 1.5	34.7	< 0.0001	24.5 (6.6; 91.8)
Age	7.4	0.007	5.3 (0.24; 11.2)
E-wave deceleration time <140 ms	4.2	0.04	13.4 (4.4; 44.7)

*calculated for age > 75 years; †calculated for heart rate at admission > 100 beats/min; ‡calculated for Vp < 45 cm/s; **calculated for peak creatine kinase MB > 125 IU/liter.
CI = confidence interval; MI = myocardial infarction. All other abbreviations as in Table 3.

Mitral filling pattern. Mitral filling pattern was within normal limits in 59 patients (54%); in 27 patients (24%) a pattern of impaired relaxation was seen, and in the remaining 24 patients (22%), a restrictive mitral filling pattern was seen. In patients with normal appearing mitral filling pattern and E/Vp <1.5, 3 of 40 (8%) had signs of in-hospital heart failure. There were no deaths in this group. In 19 of 59 patients (32%) with normal appearing mitral filling pattern, E/Vp was ≥1.5, suggestive of LV mitral filling pattern was actually pseudonormal. In this group, 18 of 19 (95%) had signs of in-hospital heart failure ($p < 0.0001$), and 6 of 19 patients (32%) died ($p = 0.001$, Fisher exact test).

Reproducibility. Inter- and intraobserver variability expressed as mean percent error of Vp was determined to be 7.6% ± 3.8% and 8.3% ± 6.4%.

DISCUSSION

Color M-mode Doppler echocardiography. Where pulsed wave Doppler echocardiography allows determination of time and velocity at a single location, the color M-mode technique has the ability to visualize the propagation of flow along the entire length of the LV throughout diastole, thereby allowing analysis of time, velocity and space (17–24). Reduced Vp has been shown to be present during myocardial ischemia (19,20) and in the acute phase of MI (21). Combined hemodynamic and color M-mode Doppler echocardiographic studies have indicated that Vp

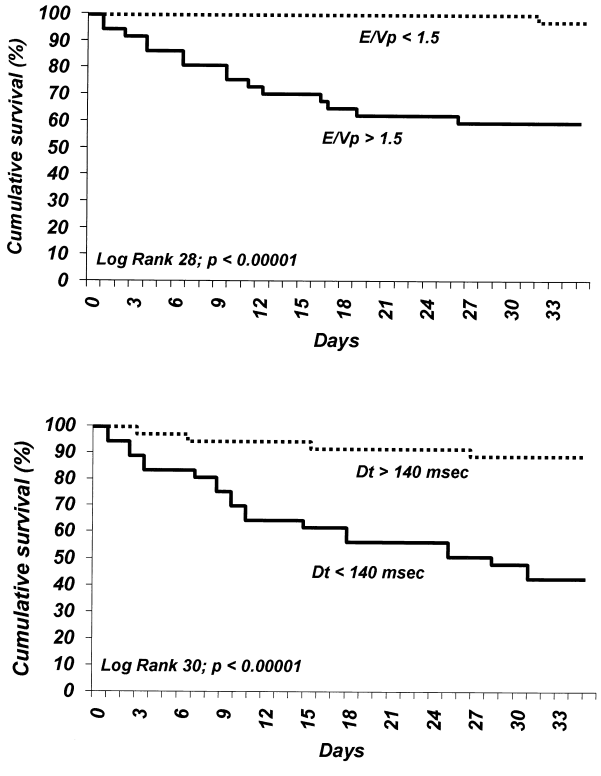

Figure 3. Effect of diastolic function on cardiac survival. **Top:** Kaplan Meier curves in patients grouped after the ratio of peak E wave velocity and flow propagation velocity (E/Vp). **Bottom:** Kaplan Meier curves in patients grouped after E-wave deceleration time (Dt).

Table 5. Univariate Cox Regression Analysis and Cox Proportional Hazards Analysis of Predictors of Cardiac Death

	Wald Chi-Square	p Value	Relative Risk [95% CI]
Univariate Cox Analysis			
E-wave deceleration time < 140 ms	21.3	< 0.0001	7.3 (3.1; 16.9)
Systolic blood pressure	13.4	0.0003	3.0 (1.4; 4.6)*
E/Vp ≥ 1.5	11.4	0.0007	3.1 (0.4; 23.4)
Wall motion index > 1.7	11.0	0.0009	4.5 (2.0; 10.1)
Highest Killip class ≥ II	11.0	0.0009	3.7 (0.4; 22.1)
Age	10.4	0.001	4.5 (1.5; 7.6)†
Heart rate at admission	8.1	0.005	2.7 (0.8; 4.6)‡
Vp	8.0	0.005	1.9 (0.6; 3.2)**
Ejection fraction < 0.40	2.8	0.09	
Peak creatine kinase MB	1.7	0.18	
Reperfusion therapy	1.4	0.24	
Cox Proportional Hazards Analysis			
E-wave deceleration time < 140 ms	9.3	0.002	2.8 (1.1; 6.7)
E/Vp ≥ 1.5	6.0	0.01	2.0 (0.3; 15.7)
Age	4.5	0.03	1.9 (0.4; 3.5)†

*calculated for systolic blood pressure < 100 mm Hg; †calculated for age > 75 years; ‡calculated for heart rate at admission > 100 beats/min; **calculated for Vp < 45 cm/s.
CI = confidence interval. All other abbreviations as in Table 4.

could represent a noninvasive index for assessment of LV relaxation (17–19). Using Vp alone as an index for outcome stratification would, therefore, include patients with impaired relaxation but normal preload (low E and low Vp). These patients with only mild diastolic dysfunction would be expected to have a good prognosis and a low risk of heart failure (3–5). In contrast, patients with impaired relaxation and elevated filling pressures exhibit prominent E and low Vp (17,18,20), and these patients would be expected to have a higher risk of adverse outcome. Based on these asumptions and a strong correlation between E/Vp and LVEDP (22,23), it was decided in this study to investigate the prognostic value of E/Vp rather than Vp alone.

Heart failure complicating MI. In this study, 48% of patients had signs of in-hospital heart failure, which is consistent with earlier reports (5,7,28). Several previous studies have shown good correlation between symptoms of heart failure and diastolic dysfunction (5–7,11,29). In the acute phase of MI, restrictive filling has shown to be predictive of development of heart failure (5,6), probably due to marked elevation of LVEDP (30). Elevated filling pressure is thought to increase left atrial pressure, producing shortness of breath and signs of pulmonary congestion. In this study, restrictive filling identified patients at risk of developing in-hospital heart failure. However, E/Vp ≥1.5 was an even better predictor of in-hospital heart failure. Previous studies have indicated that E/Vp ≥1.5 is suggestive of moderately elevated LVEDP (22,23), whereas restrictive filling is suggestive of a severely elevated LVEDP (30). As a substantial proportion of patients with only moderately elevated LVEDP would be expected to have signs and symptoms of heart failure, this may help in explaining E/Vp being more sensitive than restrictive filling in predicting in-hospital heart failure. Our results showing that Doppler diastolic variables are more predictive of heart failure as compared with systolic variables are consistent with previous reports in MI (5,6) and in congestive heart failure (10,11,29).

Prognostic implications. The outcome rate in this study is very high. This can probably be related to the study design, where no selection based on age, eligibility for thrombolysis, etc. were done that possibly could exclude high risk patients. This is supported by the Trandolapril Cardiac Evaluation (TRACE) Study (1,31) in which 7,001 unselected consecutive patients with MI were screened for inclusion in the trial. The target population was high risk patients with LV ejection fraction <35%. Mortality in patients included in the trial was 24%, which was identical to the mortality of the entire screening population. The highest mortality of 54% was seen in patients excluded from the trial (1). The mortality of 21% in this study is not significantly different from the one month mortality of 17% in the TRACE screening population ($p = 0.27$).

Several previous investigations have shown restrictive filling to be a strong independent predictor of adverse outcome in dilated (9–11,13) and infiltrative (14) cardiomyopathies. Recently, Nijland et al. (8) reported short E-wave deceleration time to be the single best predictor of cardiac death in hospital survivors after MI. Furthermore, the predictive value of a short Dt is preserved in atrial fibrillation (32), and reversal of restrictive to nonrestrictive filling pattern seems to improve the prognosis of patients

with ischemic and idiopathic cardiomyopathy (12). In this study short Dt measured early after first MI identified a subgroup of patients with a poor prognosis (58% died within 35 days), and short Dt proved to be the strongest predictor of prognosis after MI. However, due to the confounding effects of LV relaxation and LV compliance upon Dt (and E/A ratio), the value of nonrestrictive filling is limited in predicting outcome. This study indicates E/Vp to be superior to traditional systolic and clinical variables in predicting prognosis, and a group of patients with E/Vp <1.5 seemed to have a very favorable prognosis. Therefore, a combination of E/Vp and E-wave deceleration time may be a simple tool to identify patients at low risk (E/Vp < 1.5 and nonrestrictive filling), at intermediate risk (E/Vp ≥ 1.5 and nonrestrictive filling) and at high risk (restrictive filling) of adverse outcome after MI.

Diastolic LV filling pattern. The diastolic filling pattern depends on multiple interrelated events, but, simplified, the diastolic filling can be considered to depend on active relaxation and effective operating chamber compliance (4,5,33). These properties have an opposite effect on the filling pattern so it can be difficult to distinguish between a normal filling pattern (normal LVEDP) and a pseudonormal filling pattern (elevated LVEDP). Analysis of pulmonary venous flow variables may be helpful in identifying pseudonormalization (34,35) but is technically challenging and is also affected by rhythm, heart rate and respiration (36). Recently Vp has been shown to be decreased in patients with normal E/A ratio but elevated filling pressures (17,18,20) indicating this technique to be useful in detecting pseudonormal LV mitral filling patterns. In this study, one third of patients with normal appearing mitral filling patterns had an elevated (≥ 1.5) E/Vp, and, in this group, Killip class was significantly higher and outcome significantly poorer than the group with normal filling pattern and E/Vp <1.5. These results indicated that E/Vp ≥ 1.5 and normal appearing mitral filling probably represent a pseudonormalized LV mitral filling pattern.

Study limitations. In this Doppler echocardiographic study, no invasive hemodynamic procedures were performed. However, both transmitral Doppler recordings (20,30,37) and color M-mode recordings (17,18,20) have previously been investigated with simultaneous invasive measurements, and these studies served as the scientific basis for this study. Our results indicating that a normal transmitral filling pattern and E/Vp ≥ 1.5 represent pseudonormalized transmitral filling must, however, be interpreted with caution due to the lack of invasive measurements in the study. Age was significantly higher in patients with high E/Vp. However, no correlation between age and E/Vp was found between healthy volunteers. This is consistent with a previous study (38) where flow propagation was found to decrease with age. However, the age dependent decline of Vp was accompanied by a similar decline in peak E-wave velocity leaving E/Vp unchanged. Among patients with E/Vp <1.5, thrombolysis was performed, and patency of infarct related artery was achieved more often than in the group with E/Vp ≥ 1.5. However, these differences were not statistically significant, and performance of reperfusion therapy did not prove to be a predictor of outcome. Performance of, and outcome of, reperfusion therapy are, therefore, not considered to have affected the present results significantly. Heart rate and presence of mitral regurgitation were not significantly different in the groups and are unlikely to have a significant impact on our results. The method of tracing Vp has the advantage of not requiring special computer software but is prone to subjectivity. However, the inter- and intraobserver variability were within reasonable limits. In this study, the population was relatively small and the follow-up time short, but the outcome rate was high, which compensated for a small sample size.

Conclusions. This Doppler echocardiographic study in an unselected consecutive population with first MI demonstrated that E/Vp measured with color M-mode is easily obtainable and that E/Vp is a strong predictor of in-hospital heart failure. The ratio of peak E-wave velocity to flow propagation velocity is also superior to systolic variables in predicting 1 month cardiac death although a restrictive transmitral filling pattern is the most powerful predictor of short-term cardiac death. Finally, as previously reported, E/Vp also appeared useful for identifying pseudonormal mitral flow velocity patterns. The results suggest that these Doppler variables may be simple tools to rapidly risk stratify patients with first acute MI.

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