

Transthoracic Doppler echocardiography assessment of left anterior descending artery flow in patients with previous anterior myocardial infarction

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Aim We tested the hypothesis that shortening of diastolic pressure half time (PHT) of left anterior descending (LAD) coronary flow in patients with old reperfused anterior myocardial infarction (MI) is related to the presence of permanent myocardial damage of the reperfused area.

Methods and results We studied 49 patients divided into: group A: 15 patients with previous anterior MI and evidence of myocardial scar; group B: 10 patients with previous anterior MI and no evidence of myocardial scar and group C: 24 patients without anterior MI. All patients underwent coronary angiography at least 6 months after an index event and any reperfusion procedure. Group A patients had lower PHT (199 ± 62 ms) than group C (377 ± 103 ms, $p = 0.0001$) and group B (316 ± 154 ms, $p = 0.029$) patients. No other LAD flow velocity parameter differed among the 3 groups. A PHT value of 265 ms discriminated patients with scarred anterior wall with a sensitivity of 79% and a specificity of 94% (0.88 , $p < 0.001$).

Conclusion Shortening of the LAD flow diastolic PHT in patients with remote, reperfused anterior MI reflects scarred myocardial tissue in the anteroapical wall while patients who maintain diastolic wall thickness after an acute coronary syndrome have PHT similar to patients without anterior MI.

Introduction

Patients with previous anterior myocardial infarction (MI) and patent left anterior descending coronary artery (LAD) represent an increasingly common clinical entity. They raise significant clinical questions not only in the acute but also in the chronic phase of the coronary occlusion.^{1,2} The characteristics of LAD flow in patients with remote reperfused anterior MI have not been precisely defined in the chronic phase. The mid-distal portion of the LAD can be detected with a high success rate, using high frequency transthoracic Doppler echocardiography (TDE), enabling the assessment of flow velocity and velocity pattern in the vessel.^{3,4} Significant variation of this flow pattern has been noted among patients in different clinical situations.^{5–7} The magnitude of peak diastolic velocity has been related to the TIMI flow grade but not to the degree of epicardial vessel stenosis.² The no-reflow phenomenon, which leads

to poor functional recovery of the infarcted area, has been related to a steep deceleration of diastolic velocity.^{8,9} However, this finding in patients with previous MI has been attributed by Voci et al.¹⁰ to technical error. We tested the hypothesis that in patients with old reperfused anterior MI, the diastolic pressure half time (PHT) of coronary flow will be shorter in those with apical scarring compared to patients without echocardiographic evidence of apical necrosis.

Patients and methods

We studied 55 consecutive patients with known or suspected coronary artery disease admitted for coronary arteriography. Patients with MI or coronary intervention during the 6 months prior to catheterization were excluded from the study. The study was approved by the hospital committee on human research.

Six patients had no detectable LAD Doppler flow signal and were proven to have totally occluded LAD by subsequent coronary arteriography. Therefore the study population consisted of the remaining 49 patients. Twenty-five patients had previous anterior MI, as

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indicated by electrocardiographic findings and troponin elevation documented during an acute coronary syndrome. Thirty-three patients had undergone a revascularization procedure, 16 of them percutaneous intervention of the LAD with stent placement, and 17 surgical grafting with the left internal mammary artery implanted to the LAD.

All patients underwent complete echocardiographic examination,¹¹ for measurement of left ventricular dimensions and left ventricular ejection fraction (LVEF) by the Simpson's rule. Apical scar was defined as an akinetic or dyskinetic area with diastolic wall thickness below 5 mm and increased echogenicity when compared to adjacent myocardial segments.¹² After the completion of the standard echocardiographic examination, LAD flow was detected using a 4–6.7 MHz or a 1.7–3.4 MHz multifrequency transducer (GE-Vingmed VIVID 7, Norway). A modified apical 2-chamber view was used, and the flow signal was located by color flow mapping as flow towards the transducer containing a dominant diastolic signal. The velocity range was lowered to 10 mm/s in cases of weak flow signal, to detect low LAD velocity at the apical region. Care was taken to avoid interference of myocardial velocity or pericardial motion. The sample volume size was set at 3 mm. The sampling of the flow by pulsed wave Doppler was obtained at the perpendicular segment of the vessel in a parallel fashion to the Doppler beam to avoid underestimation of the peak and mean velocities.^{2,4,13–15} PHT of diastolic LAD flow was measured in all patients with patent LAD. Peak and mean diastolic flow velocity and diastolic time velocity integral were also measured. Systolic peak, mean and systolic time velocity integral were detected and measured in 35 patients. Five consecutive beats were measured and averaged for each patient. No angle correction was used. Images were digitally stored and analyzed before cardiac catheterization. Subsequently, patients were divided into 3 groups; group A consisted of 15 patients with old MI, and anteroapical scar, group B of 10 patients with previous MI, preserved diastolic wall thickness and normal echogenicity of the anteroapical wall and group C of 24 patients without history of MI. All patients underwent elective, routine coronary arteriography within 2 days from the echocardiographic study.

Statistical analysis

Quantitative variables are expressed as mean \pm 1 SD. Comparisons of quantitative variables were performed by the t-test for independent samples and the one-way analysis of variance with the Bonferroni correction for multiple comparisons. Comparisons of categorical variables were analyzed by the χ^2 test. Cutoff point for PHT was detected by receiver operating curve (ROC) analysis and sensitivity and specificity were calculated. Binary logistic regression analysis was used to distinguish significant factors of the presence of scar and explore interaction between them. The statistical significance was set at the level of 5%.

Results

Demographic and clinical characteristics of the 3 groups are shown in *Table 1*. The degree of LAD stenosis and the percentage of patients who had a reperfusion procedure were similar in groups A, B and C. Patients of group A had similar LVEF to patients of group B ($p = 0.14$), but lower than group C ($p = 0.001$). Group B LVEF was also lower than group C ($p = 0.003$). Group A patients had diastolic volume (227 ± 60 ml) which was similar to group B diastolic volume (200 ± 70 ml, $p = 0.3$) and greater than diastolic volume of group C (142 ± 49 ml, $p = 0.001$ with group A and $p = 0.042$ with group B). Group A patients had shorter PHT than group

C ($p = 0.0001$) and group B ($p = 0.029$) patients. Group C did not differ from group B in PHT ($p = 0.3$). No other LAD flow velocity parameter differed among the 3 groups (*Table 2*). Typical recordings of a group A and a group C patient are illustrated in *Figure 1*. By ROC analysis (area under the curve 0.88, $p < 0.001$), a PHT value of 265 ms depicted group A patients with a 79% sensitivity and 94% specificity (*Figure 2*). By stepwise regression, PHT was the only significant factor related to the presence of scar when examined together with LVEF ($p = 0.018$). The interaction between PHT and LVEF was non-significant ($p = 0.472$).

Discussion

The findings of this study suggest that patients with anteroapical myocardial scar due to remote anterior MI exhibit a rapid deceleration of the diastolic LAD flow, while patients without necrosis despite old MI exhibit flow pattern similar to patients without previous MI. Most of the studies on this subject^{2,8,9} relate flow characteristics of the LAD to viability indices derived during an acute coronary syndrome. The assessment of viability during the acute phase using the 'open perforator hypothesis' or the 'no-reflow phenomenon' may have contributed to discrepancies between studies.^{8,16} Conversely, in the chronic phase, myocardial scar defined as diastolic wall thickness below 5 mm, akinesis or dyskinesis and increased echogenicity, is an accepted determinant of non-viable tissue.¹²

In a previous report using flow wire and myocardial contrast echocardiography it was shown that patients with reperfused acute myocardial infarction and no-reflow phenomenon exhibit a steep deceleration rate when compared to patients without no-reflow.⁹ More recently, another study from the same group indicated that similar results can be obtained using TDE.⁸ They suggest that this finding indicates microvascular damage. Our study shows that this steep deceleration pertains also to the chronic phase that follows an acute ischemic event, indicating permanent microvascular damage depicted by a cutoff point of 265 ms for the PHT of the LAD flow.

The physiologic significance of the LAD diastolic slope is contradictory. It had been suggested that a steep slope would indicate better patency of the LAD hydraulic system as in the case of mitral stenosis.¹⁰ The use of the mitral stenosis physiologic paradigm is not entirely justified in the case of LAD flow, because the main factor that affects flow characteristics is not the patency but the capacity of the hydraulic system. Probably, the flow paradigm pertaining more accurately to these events is the one of aortic regurgitation.¹⁶ In patients with anterior MI and extensively damaged microcirculation, the remaining capillaries distal to the sampling point fill rapidly, because of their reduced number, impaired vasodilatation and increased resistance. This rapid filling leads to a fast abolition of the driving pressure gradient which shortens diastolic PHT of the LAD flow.^{17,18} In patients who, despite the ischemic event, maintain diastolic wall thickness (group B in our study population), the capacity of the microvascular bed permits a flow deceleration similar to the one that characterizes patients with no previous acute coronary syndrome. Technical error¹⁰ is unlikely to explain the steep slope of the diastolic LAD velocity in patients with anteroapical scar, because detection of the LAD flow is easier in patients without wall

Table 1 Demographic and clinical characteristics

	Group A (n = 15)	Group B (n = 10)	Group C (n = 24)	P-value
Age (yrs)	61 ± 15	55 ± 7	63 ± 11	0.2
Heart rate (beats/min)	68 ± 11	70 ± 18	62 ± 8	0.14
M/F	14/1	10/0	21/3	0.9
LVEF (%)	31 ± 5**	40 ± 12*	53 ± 10* **	0.001 0.003* 0.001**
Previous revascularization, patients (%)	12 (80)	7 (70)	14 (58)	0.37
Surgical	9 (60)	4 (40)	4 (16.7)	0.018
Percutaneous	3 (20)	3 (30)	10 (41.7)	0.68
LAD stenosis >70%, patients (%)	4 (27)	4 (40)	7 (29)	0.83
Cardiac medications, patients (%)				
Aspirin	15 (100)	10 (100)	24 (100)	0.99
Clopidogrel	5 (33)	4 (40)	16 (67)	0.10
β-Blockers	15 (100)	10 (100)	24 (100)	0.99
ACE-I	14 (93)	8 (80)	20 (83)	0.58
Nitrates	7 (47)	6 (60)	12 (50)	0.80

M/F: male to female ratio, LVEF: left ventricular ejection fraction, LAD: left anterior descending coronary artery, ACE-I: angiotensin converting enzyme inhibitors.

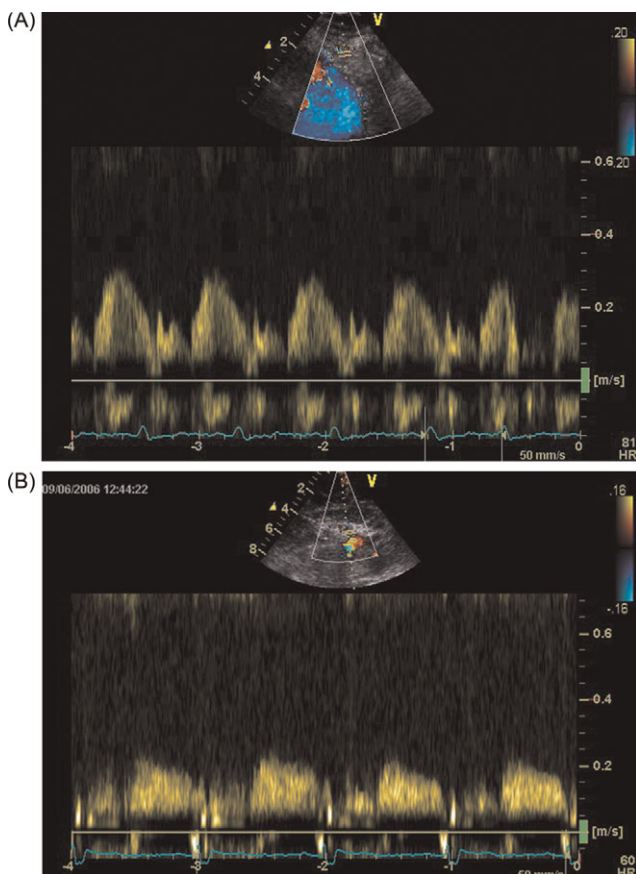


Figure 1 (A) LAD flow pattern of a group A patient. PHT was 157 ms. (B) LAD flow pattern of a group C patient. PHT was 535 ms.

motion artifacts. However, in our study LAD diastolic flow was detected in all patients who had patent vessel, while the systolic component of the flow was detected with a success rate greater than 70%.

Both PHT and diastolic deceleration time have been used in previous studies.^{8,16,19} PHT represents the time required for the diastolic driving pressure gradient to reach the half of its initial diastolic value. In this sense this measurement is relatively independent from the initial velocity and heart rate and is the measurement we preferred in our study.

Several methods have been used to detect myocardial viability.^{20,21} Diastolic wall thickness <5 mm had 100% negative prognostic accuracy for 1 year functional recovery.¹² In our study patients with this finding (group A) had clearly steeper diastolic LAD flow and decreased PHT. In another report end-diastolic wall thickness ≤6 mm virtually excluded the potential for recovery of myocardial function.²² Group A patients had lower LVEF than groups B and C. Groups A and B had greater diastolic volumes than group C. Could these differences in LVEF and diastolic volume have caused or contributed to the changes of LAD flow pattern? Obviously a selection bias exists between groups. Group A patients were selected to have anteroapical scar; therefore, the lower LVEF was expected. We found that when LVEF and diastolic volume were inserted in the multiple regression model, no interaction was observed between these two variables and PHT.

The steep slope of LAD flow reappears in the acute phase⁸ before the ventricular remodeling or the reduction of LVEF. In a study that followed up the LAD flow pattern for 3 weeks after reperfused acute anterior MI, it was shown that persistence after day 7 of the steep deceleration was a predictor of ventricular remodeling.²³ That means this parameter is rather causal than a consequence of remodeling, and ensues from local microcirculatory damage and not from globally impaired ventricular function or increased wall stress. In a more recent study, which analyzed the timing of appearance of flow characteristics after an acute MI, the shortening of deceleration was the first to appear.²⁴ It was shown that this steep deceleration does not persist for more than 3 weeks in the vast majority (16/19) of their patients. The authors propose recanalization or

Table 2 LAD flow characteristics

	Group A (n = 15)	Group B (n = 10)	Group C (n = 24)	P-value
PHT (ms)	199 ± 62*, **	316 ± 154**	377 ± 103*	0.0001 0.0001* 0.029**
Pdia (cm/s)	29 ± 9	36 ± 24	25 ± 9	0.12
Mdia (cm/s)	20 ± 6	27 ± 20	19 ± 7	0.14
VTID (cm)	9.9 ± 3.5	12.1 ± 7.1	10.5 ± 4.3	0.54
Systolic flow detection, patients (%)	10 (66.6)	5 (50)	20 (83.3)	0.21
Psys (cm/s), 35 patients	16 ± 5	16 ± 6	14 ± 5	0.76
Msys (cm/s), 35 patients	12 ± 3	11 ± 4	11 ± 4	0.63
VTIS (cm), 35 patients	3.1 ± 1.7	2.4 ± 1.5	2.6 ± 1.3	0.59

PHT: pressure half time of diastolic LAD flow, Pdia: peak diastolic LAD velocity, Mdia: mean diastolic LAD velocity, VTID: time velocity integral of diastolic LAD flow, Psys: peak systolic LAD velocity, Msys: mean systolic LAD velocity, VTIS: time velocity integral of systolic LAD flow.

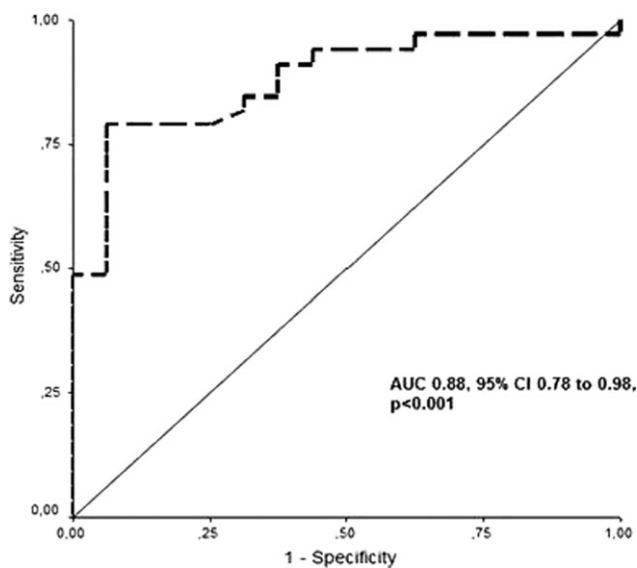


Figure 2 Receiver operating characteristic curve of PHT of diastolic LAD flow. PHT value of 265 ms depicted group A patients with 79% sensitivity and 94% specificity.

angiogenesis of the microcirculation as possible mechanisms to explain the improvement of the deceleration slope. This should be the case in patients with viable myocardium. Conversely, our data indicate that in the chronic phase post MI in patients with scar this pattern persists. One may suggest that in patients who end up with apical scar, microcirculation does not recover, and this is reflected on the shortened PHT.

In conclusion, in patients with remote, reperfused anterior MI and echocardiographic evidence of anteroapical scar, the diastolic LAD flow pattern exhibits steep deceleration while patients who, despite previous MI, maintain diastolic wall thickness have more prolonged deceleration similar to that seen in patients without anterior MI.

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