VIA MEDICA

ORIGINAL ARTICLE

Folia Cardiol.
2006, Vol. 13, No. 4, pp. 293–301

ISSN 1507–4145

The prognostic value of contrast echocardiography, electrocardiographic and angiographic perfusion indices for the prediction of left ventricular function recovery in patients with acute myocardial infarction treated by percutaneous coronary intervention

Krystian Wita, Artur Filipecki, Wojciech Wróbel, Agnieszka Drzewiecka-Gerber, Przemysław Węglarz, Maciej Turski, Anna Rybicka-Musialik, Zbigniew Tabor, Mariola Nowak, Jolanta Krauze, Jan Szczogiel, Janusz Drzewiecki and Maria Trusz-Gluza

1st Department of Cardiology, Silesian Medical University, SPSK 7, Katowice, Poland

Abstract

Background: *Fast and effective culprit artery patency restoration is important in acute myocardial infarction (MI) but does not ensure that tissue perfusion related to a better prognosis in the long-term follow-up is achieved. In this study we compared the prognostic value of myocardial perfusion contrast echocardiography with other well-known electrocardiographic and angiographic indices of preserved tissue perfusion.*

Material and methods: *We studied 114 consecutive patients, of whom 85 were male, aged 57.9 ± 11 years, within 12 hours of the onset of symptoms of their first anterior myocardial infarction. These were treated with primary PCI, after which PCI myocardial blush grading was assessed (MBG 0–1 no perfusion, 2–3 normal perfusion). One hour after PCI a reduction of > 50% in the sum of ST-segment elevation (ΣST 50%) was assessed as an indicator of perfusion restoration. During the first 24 hours continuous ECG monitoring recorded reperfusion arrhythmias (RA) and the time required for ST-segment reduction to exceed 50% in the single lead with the highest ST elevation (Δt ST 50%). On the next day of MI, after LVEF evaluation, real-time myocardial contrast echocardiography (RT-MCE) was performed to assess perfusion in dysfunctional segments. The reperfusion index as an average of the dysfunctional segment perfusion score was determined. Regional and global LV function was assessed again one month after MI. An LVEF increase of over 5% divided the patients into two groups: group A with LVEF improvement (72 pts) and group B without LVEF improvement (42 pts).*

Results: *In group A baseline LVEF was 41.9 ± 7.1% and in group B it was 38.9 ± 7.4% (p = NS). The reperfusion indices were 1.59 and 0.78 (p < 0.001) respectively. MBG 2–3 occurred more often in group A (64%) than in group B (34%) p<0.001. Σ ST50% and Δt ST 50%, after determination of the cut point on the ROC curve (61 min), occurred in 47 and 48 patients in*

Address for correspondence: Dr med. Krystian Wita
1st Department of Cardiology
Silesian Medical University, SPSK 7
Ziołowa 47, 40–635 Katowice, Poland
Tel: +48 32 359 87 35, fax: + 48 32 252 36 58
e-mail: welwetek@poczta.onet.pl
Received: 28.11.2005 Accepted: 7.04.2006

Editorial p. 269

group A and 17 and 16 patients in group B respectively. The accuracy of the tests under discussion for LVEF prognosis was 76.3%, 64%, 63.2% and 64.9% for RT-MCE, MBG, ΣST50% and Δt ST 50% respectively.

Conclusions: *Myocardial perfusion echocardiography had a high prognostic value for the prediction of LV global function improvement. It turned out to be the best predictor among the other angiographic, echocardiographic and electrocardiographic markers.* (Folia Cardiol. 2006; 13: 293–301)

myocardial contrast echocardiography, myocardial perfusion, acute myocardial infarction

Introduction

The contemporary treatment of acute myocardial infarction aims not only at effective infarct-related artery patency restoration [1–3] but also, more interestingly, at effective restoration of tissue perfusion related to improved prognosis and better left ventricle contractility in long-term follow-up when compared with patients with patent infarct-related artery but distorted tissue perfusion [4, 5]. Impaired tissue perfusion is present in 25–50% of patients, despite fast and full flow restoration in the initially closed artery, especially in anterior wall infarction, and determines the higher mortality in those patients [6]. This could be due to microembolisation, oedema or intra-wall haemorrhage in the small vessels, the phenomenon known as "no reflow" [7].

There is no "gold standard" to assess microcirculation in acute myocardial infarction: angiographic blush grading (MBG) utilising a degree of myocardial contrasting or the reduction of ST-segment elevation from an 12-lead electrocardiogram are simple methods utilised for the assessment of tissue perfusion after infarct-related artery recanalisation.

Perfusion myocardial contrast echocardiography (MCE), especially in real-time imaging (RT-MCE) and with second generation contrast agent, is being used increasingly frequently because it combines the advantages of several non-invasive techniques to elucidate the viability of infarcted area segments with distorted contractility.

In an era in which this method is developing rapidly it is useful to compare the value of electrocardiography, angiography (MBG) and echocardiography (RT-MCE) for perfusion assessment and prediction of left ventricular function recovery after myocardial infarction.

The purpose of the study was to compare the prognostic value of myocardial contrast echocardiography with other established electrocardiographic and angiographic perfusion indices in the prediction of global systolic left ventricular function recovery in patients with acute anterior myocardial infarction treated with early primary percutaneous intervention (PCI). We tried to define the optimal prognostic algorithm by utilising demographic, electrocardiographic, echocardiographic and angiographic tissue perfusion indices to predict global systolic function restoration in a one-month follow-up.

Material and methods

One hundred twenty nine patients were included in the study, all of whom had been admitted to our centre within 12 hours of the onset of chest pain. After a diagnosis of first myocardial infarction, anterior wall only, successful PCI was performed (TIMI 3 at the end of the procedure). Anterior wall infarction was defined by the following criteria: presence of prolonged chest pain > 20 minutes, at least 2 mm ST-segment elevation in leads V1–V3, at least 1 mm ST elevation in the other precordial leads or in I, aVL, or a newly diagnosed left bundle branch block. The patients were over 18 years of age and their informed consent was obtained. The study was approved by the local ethics committee.

Exclusion criteria included: a history of any previous myocardial infarction, hypertrophic cardiomyopathy, electrical instability, an implanted pacemaker or cardioverter-defibrillator, the absence of full artery flow restoration, a significant residual stenosis of the infarct-related artery (> 50%), an inability to identify the infarct-related artery, female gender with childbearing potential and significant valvular heart disease.

Conventional echocardiography

Resting echocardiography was performed during the second 24 hours after PCI immediately before contrast study with the Vivid 7 system (GE Vingmed, Norway) in typical apical views. The wall motion score index (WMSI) was calculated as a ratio of the sum of the contractility indices and the number of visualised segments. Systolic and diastolic left ventricular volumes were assessed as the arithmetic mean of volumes measured in a 2-chamber and 4-chamber view with the Simpson method.

At 30-day follow-up the second resting echocardiography study was performed for regional and global left ventricular function. Improvement of LVEF was defined as an increase of at least 5% in comparison with the initial examination and patients were divided into two groups: group A with LVEF improvement and B without it.

Real-time myocardial perfusion echocardiography

Perfusion echocardiography was performed during the second 24 hours of myocardial infarction, after PCI in the left lateral position utilising "Optison" (Mallinckrodt) infused to a peripheral vein during as a slow bolus of 0.3–0.5 ml for every of three apical views. Dose and delivery speed of the contrast agent was modified individually according to the artefacts of each individual case.

Real-time perfusion imaging was obtained with the use of low mechanical index visualisation (0.10–0.16), which enables disruption of contrast bubbles to be eliminated. The image gain and depth were optimised individually for each patient and were not changed during the entire study. The ultrasound beam was focused on the mitral ring level.

After the LV cavity and walls had been filled with contrast and a dynamic stability state had been achieved, disruption of contrast microbubbles in the myocardium was performed with the Flash method [9], that is with a series of several ultrasound impulses of a high mechanical index (MI). Then, in real time during low MI, several cycles, usually 15, were analysed [10] with assessment of the degree of replenishment of the contrast agent to the myocardium.

Segments were scored as normal, hypokinetic, akinetic or dyskinetic. Only hypokinetic, akinetic, and dyskinetic segments were included in the subsequent analysis, forming the area of interest (RA, "risk area") [11]. Myocardial opacification as a perfusion degree in every dysfunctional segment was classified as normal, homogenic perfusion — 2, partial perfusion — 1 and without perfusion — 0. The regional contrast index was defined as the ratio of the sum of the regional perfusion indices to the number of dysfunctional segments [11]. A segment was assessed as viable when homogenic opacification (score = 2) was present and preserved global microvascular integrity was defined as homogenic, contrasting at least 50% of dysfunctional segments.

Coronary angiography and PCI

In all patients coronary angiography was performed with infarct-related artery TIMI flow assessment, and then PCI was performed. After successful PCI in the left anterior descending artery the TIMI flow was reassessed and angiographic perfusion assessment was performed with myocardial blush grade (MBG) [12]. MBG was defined as 0 — no contrast in the myocardium in IRA area, 1 — minimal myocardial contrasting, 2 — moderate myocardial contrasting, smaller than in the reference area, 3 — normal contrasting comparable with the reference area. Patients with MBG 0–1 grades were classified as the group without perfusion and patients with MBG 2–3 were defined as the group with preserved perfusion. The optimal angiographic result was defined as TIMI 3 flow restoration with maximal residual stenosis $< 30\%$.

Electrocardiographic analysis

A 12-lead electrocardiogram (ECG) was performed just before and 60 minutes after PCI. From the first tracing maximal ST elevation from a single lead (Max ST) and the sum of ST-segment elevations from the precordial leads and I, aVL were recorded. On the basis of the second ECG the patients were divided into two groups, one with a reduction in ST-segment elevation and one without it. On the basis of the TIMI 14 study, tissue perfusion was defined as a cut-off point of at least 50% of the sum of the ST-elevation (ΣST 50%) reductions [13, 14].

From continuous 24-hour 12-lead monitoring with the Dash 4000 system (GE) the time to a 50% ST-segment reduction in elevation from a single lead with Max ST (Δt ST 50%) was recorded [15]. Patients with Δt ST 50% lower than the cut-off point determined from the ROC curve were considered to present preserved perfusion.

As reperfusional arrhythmias (RA) we recorded the occurrence of accelerated idioventricular rhythm, ventricular tachycardia, ventricular fibrillation, pathological bradycardia or paroxysmal atrial fibrillation after infarct-related artery recanalisation.

Statistics

Continuous variables are presented as means ±standard deviation (SD) and compared with Student's t-test or ANOVA. Spearman's correlation test was used when appropriate. Categorical variables are presented as absolute values and/or percentages and compared with the χ^2 test. For variables presenting an abnormal distribution non-parametric tests were used. From the ROC curve the optimal cut-off value for the time to maximal ST-segment elevation reduction was determined to obtain the best discrimination of patients with LVEF improvement. Logistic regression analysis was performed to find the best combination of factors influencing LVEF improvement.

Results

Of the 129 patients initially enrolled with acute anterior myocardial infarction 2 patients died as a result of haemodynamically unstable ventricular tachycardia and ventricular fibrillation during the first 24 hours before the study echocardiographic examination. In eight patients we failed to assess all 16 segments in the initial echo study and in a further five patients the RT-MCE perfusion signal in the area of interest could not be interpreted. These patients were excluded from analysis. Finally 114 patients aged 57.9 ± 10.7 years were examined, 85 of them males (Table 1). Concomitant diseases included arterial hypertension in 47 patients and diabetes in 19 patients. The mean time from symptom onset to reperfusion was 291 ± 192 minutes. Mean LVEF in the study population was 40.8 ± ± 7.3% in the initial study and this increased to 49.1 ± ± 14.8% at the one-month follow-up. Similarly, initial WMSI was 1.41 ± 0.21 and lowered to 1.29 ± ± 0.29 ($p < 0.05$) in the second examination. Preserved angiographic perfusion (MBG 2–3) was found in 53% of patients. The perfusion index from the dysfunctional area in the MCE was 1.28 ± 0.66. The mean duration of 50% ST-segment elevation reduction was long: 597 ± 930 min.

A weaker, albeit statistically significant, correlation was found between MBG perfusion and LVEF at 30 days ($r = 0.34$, $p < 0.0003$).

According to whether or not there was an LVEF increase at 30 days, the study population was divided into two subgroups: group A consisted of 72 patients with global systolic function improvement, while group B consisted of 42 patients without it. Initial LVEF in group A was 41.9 ± 7.1% as compared to 38.9 ± 7.4% in group B (p = NS) and the reperfusion indices were 1.59 and 0.78 ($p < 0.001$) respectively. At 30-day follow-up LVEF was significantly higher (57.4 ± 10.8%) in group A ($p < 0.05$) and not significantly lower in group B (34.9 ± 8.9%). This value was significantly lower than in group A ($p < 0.00001$). Similarly, preserved angiographic perfusion (MBG 2–3) was significantly more frequent in group A (64%) then in group B (34%), $p < 0.001$. There was a significant difference ($p < 0.001$) between the groups in the time to a 50% reduction in ST-segment elevation from the lead with the maximum elevation ($p < 0.001$): the median time was 60 min in group A and 130 min in group B. During 24-hour 12-lead ECG monitoring there was no 50% ST-segment reduction from the lead with the maximum elevation in 11 patients: 4 (5.5%) from group A and 7 from group B (19%). The remaining parameters analysed in both groups are presented in Table 2.

From the ROC curve it was determined that 61 minutes is the optimal time of 50% ST-segment reduction from the lead with the maximum elevation, predicting systolic function improvement. This allowed LVEF behaviour to be correctly predicted at 30 days in 74 patients, including 48 patients from group A. LVEF improvement prediction from this index showed a sensitivity, specificity and accuracy of 66.6%, 61.9,% and 64.9%, respectively, with an AUC of 0.6.

Table 1. Baseline characteristics of patients

Parameter	Number, percentage or mean ±SD
Number	114
Men	75%
Age [years]	57.9 ± 10.7
Diabetes mellitus	16.6%
Hypertension	41.2%
Hypertension treatment:	
ACE inhibitors	78%
beta-blockers	30%
Time to reperfusion [min]	291 ±192
Abciximab	66%
Troponin max [μg/l]	32.5 ± 18.9
CK-MB max [IU/l]	272 ± 238
Left ventricular ejection fraction 0	40.8 ± 7.3%
Left ventricular ejection fraction 30	49.1 ± 14.8%
Wall motion score index 0	1.41 ± 0.21
Wall motion score index 30	1.29 ± 0.29
Reperfusion index	1.28 ± 0.66
Myocardial blush grade 2–3	53%
ΣST [mm]	18.1 ± 11.1
ΔtST50% [min]	597 ± 930
ΣST50%	55.6%
ACE inhibitors	93.0%
Beta-blockers	98.0%
Acetylsalicylic acid	99.0%
Statin	98%

ΣST — sum of ST elevations in I, aVL, V1–V6 leads; ΔtST50% — time to a reduction of more than 50% in the maximum ST elevations in a single lead; ΣST50% — reduction of at least 50% in the sum of ST elevations in leads I, aVL, V1–V6; 0 — initial examination; 30 — examination at the 30-day follow-up

Table 2. Baseline characteristics of patient groups

Parameter	Group A	Group B	P
Number	72	42	
Men	70.8%	80.9%	NS
Age [years]	58.0 ± 10.1	57.3 ± 11.0	NS
Diabetes mellitus	13.9%	19.0%	NS
Hypertension	47.2%	28.6%	0,07
Abciximab	58.3%	70.9%	NS
Time to reperfusion [min]	284 ± 176	314 ± 219	NS
Troponin max [μg/l]	26.97 ± 19.24	42.31 ± 14.15	0.0001
CK-MB max [IU/l]	215.3 ± 234,6	372.1 ± 216.3	0.0001
Left ventricular ejection fraction 0	41.9 ± 7.1%	38.9 ± 7.4%	NS
Left ventricular ejection fraction 30	57.4 ± 10.8%	34.9 ± 8.9%	0.00001
Wall motion score index 0	1.36 ± 0.21	1.51 ± 0.21	0.0001
Wall motion score index 30	1.19 ± 0.19	1.57 ± 0.25	0.00001
Reperfusion index	1.59 ± 0.49	0.78 ± 0.61	0.001
Myocardial blush grade 2–3	64%	34%	0.001
ΣST [mm]	15.9 ± 11.4	22.0 ± 9.5	0.001
ΔtST50% [min]	444 ± 790	844 ± 1096	0.001
ΣST50%	65.3%	40.5%	0.01

ΣST — sum of ST elevations in I, aVL, V1–V6 leads; ΔtST50% — time to a reduction of more than 50% in the maximum ST elevations in a single lead; ΣST50% — reduction of at least 50% in the sum of ST elevations in leads I, aVL, V1–V6; 0 — initial examination; 30 — examination at the 30-day follow-up

Homogenic contrasting of at least 50% of the dysfunctional segments in the RT-MCE enabled LVEF improvement at 30 days to be predicted in 58 patients from group A and 13 patients from group B with a sensitivity, specificity and accuracy of 78.4%, 69.0% and 76.3% respectively.

Angiographic MBG 2–3 perfusion was found in 61 patients and 46 of them showed 30-day LVEF improvement, as opposed to 27 patients without improvement in MBG 1–2. Thus the calculated sensitivity, specificity and accuracy of MBG were 63.8%, 64.3% and 64%, respectively. A reduction in at least 50% of the sum of ST-segment elevations at 60 minutes after PCI was found in 47 and 17 patients and reperfusional arrhythmias were present in 46 and 32 patients from groups A and B respectively. The prognostic values of all the assessments for the prediction of LVEF at 30 days are presented in Table 3.

Table 3. Indices for determining the prognostic value of the described methods for the prediction of left ventricular function improvement at the one-month follow-up. The statistical analysis was performed in order to determine the accuracy of RT-MCE in relation to other methods

Parameter	Sensitivity	Specificity	Accuracy	p
RT-MCE	78.4%	69%	76.3%	
MBG	63.8%	64.3%	64%	0.049
ΣST50%	65.3%	59.5%	63.2%	0.034
RA	63.8%	23.8%	49.1%	0.001
ΔtST50%	66.6%	61.9%	64.9%	0.049

RT-MCE — real-time myocardial contrast echocardiography; MBG — myocardial blush grade; ΔtST50% — time to a reduction of more than 50% in the maximum ST elevations in a single lead; RA — reperfusion arrhythmia; ΣST50% — reduction of at least 50% in the sum of ST elevations in I, aVL, V1–V6 leads

Univariate analysis showed that of all the risk factors tested only a history of hypertension, WMSI, MBG, abciximab usage, RT-MCE preserved perfusion, Δt ST 50% in 61 minutes, the presence of ΣST 50% and the value of ΣST significantly favour LVEF improvement at 30 days. Multiple logistic regression analysis with the inclusion of demographic data, coronary disease risk factors and electrocardiographic, echocardiographic and angiographic indices in the study population showed that a history of hypertension, RT-MCE preserved perfusion, Δt ST 50% before 61 minutes, the MBG value and ΣST were included in the LVEF improvement predictive model (Table 4). The odds ratio for LVEF improvement at 30 days was 7.53 higher for patients with preserved perfusion in RT-MCE. With this

Table 4. Logistic regression model for prediction of left ventricular ejection fraction improvement at the one-month follow-up

Parameter	Odds ratio	95% CI	P
Hypertension	3.25	1.07–9.82	0.03
MBG	1.764	1.04–2.97	0.03
ΣST	0.87	0.78–0.97	0.001
ΔtST50%	2.74	0.97–7.77	0.05
MCE	8.85	3.1–25.02	0.0001

MBG — myocardial blush grade; ΣST — sum of ST elevations in I, aVL, V1–V6 leads; ΔtST50% — time to a reduction of more than 50% in the maximum ST elevations in a single lead; MCE — myocardial contrast echocardiography

logistic regression model we could correctly predict LVEF behaviour in 89 patients, including 62 group A patients. The remaining 25 patients (10 with LVEF improvement and 15 without it) were incorrectly classified. The sensitivity, specificity and accuracy of the model were 86%, 64% and 78%, respectively.

Discussion

The angiographic patency of the epicardial coronary artery does not mean restoration of perfusion on the tissue level [16]. This was first observed in an animal model by Kloner et al. [7] and confirmed in humans in the early 1990s by Ito, who used MCE for assessment of the "no reflow" phenomenon [17] and concluded that infarct-related artery patency could be not connected with preservation of microvascular integrity and tissue perfusion. Direct endothelium damage during reperfusion by free radicals, changes in vascular reactivity, an intravascular accumulation of erythrocytes, neutrocytes and platelets producing mechanical obstruction of the microvessels, microhaemorrhages or myocyte oedema are postulated for the "no reflow" phenomenon [18].

Despite the introduction of several non-invasive methods to assess tissue perfusion preservation (SPECT, magnetic contrast resonance imaging and positron emission tomography, for instance) these methods are not widely used in the everyday management of acute myocardial infarction patients owing to their limited availability and high costs. In contrast, MCE, especially in an adequate imaging regimen, combines the diagnostic advantages of the above-mentioned methods in assessment of dysfunctional segment viability in the infarction area.

Numerous papers have addressed the issue of effective and repetitive assessment of tissue reperfusion in the early phase of acute myocardial infarction [2, 4, 13, 19]. Although there have been well-documented studies assessing the value of electrocardiographic or angiographic indices of tissue perfusion, there are no comparisons of the long-term prognostic efficacy of myocardial contrast echocardiography with the other methods. On the other hand there is no satisfactory algorithm to stratify patients in acute MI by identifying patients of higher risk, those, that is, with impaired perfusion despite a patent infarct-related artery.

Prediction of global LV systolic function improvement is of the greatest importance for long-term outcome and, therefore, from the clinical point of view it is important to determine by how much LVEF should be improved for significant clinical benefit to patients. In most papers it has been accepted [20, 21] that a 5% increase of LVEF is prognostically significant. This value is based mainly on the reproducibility issue but not on empirical knowledge of the clinical outcome.

Patients with LVEF improvement at 30 days were characterised by decreased myocardial necrosis with significantly lower Troponin I and CKMB levels, despite a similar time for reperfusion and similar initial LVEF in comparison with patients who showed no improvement. This is consistent with other papers [22].

The high correlation coefficient between the reperfusion index and LVEF at day 30 in 114 of the study patients resulted in both significant LVEF improvement and a higher RCSI value. Contractility, in group B patients a slight LVEF drop, was found in the second examination.

A lower correlation was found for angiographic perfusion assessment. Despite the statistically higher MBG in patients with LVEF improvement and a significant correlation between MBG and LVEF on day 30, the value of the correlation coefficient (0.33) shows a weak connection in the study population. In our patients MBG 2 or 3 was rarer (53%) than in other studies (up to 70%), despite the similarity between our results and those of Henriques, showing a lower EF in patients with MGB 0–1 [23]. The reason for this discrepancy could be connected to patient selection. In our study the index event was the first myocardial infarction, only the anterior wall, frequently without preceding angina and with a lower frequency of collaterals. Angiographic perfusion data could be influenced by the longer time in all patients from symptom onset to catheterisation and TIMI 0–1 flow before angioplasty in comparison with other studies [24, 25].

Our results for electrocardiographic reperfusional indices — ΣST, ΣST 50% — are consistent with other studies [26, 27]. Other contrast echocardiography, blush angiography or magnetic resonance studies confirm the relationship between persistent ST-segment elevation and impaired microcirculation, despite a normal flow in the epicardial artery [12, 28, 29].

In 2004 Iwakura et al. [30] reported a very similar accuracy, with differences in sensitivity and specificity for ΣST 50%. The substantially higher sensitivity in our study resulted from the selected criterion: 50% ST-segment elevation reduction. We found this to be closer to the optimal than a 70% reduction criterion. It seems that different cut-off values for the reduction in ST-segment elevation should be implemented for anterior (50%) and inferior (70%) infarct locations [31].

Great interest has recently been aroused in comparing resting ECG ST-segment level in predefined time intervals with continuous 12-lead ECG monitoring. Serial ECG registration has several disadvantages because it is inaccurate in detecting the maximum ST elevation and cannot assess the dynamicity of ST level changes. On the other hand continuous 12-lead monitoring requires additional equipment and special personnel training. In our study the time to the 50% reduction in ST-segment elevation from the lead with the maximum elevation was found to be the most powerful predictor of LVEF recovery [32]. Among ECG indices we used continuous monitoring to assess the viability of the infarct area myocardium and not, like the others, to asses infarct-related artery patency. The values of Δt ST 50% differed between the two subgroups. In patients with LVEF recovery it was almost twice as short as in the remaining patients and the optimal cut-off point time was 61 minutes. However, the area under the ROC makes it clear that the differentiating power of this parameter is moderate at best and the sensitivity, specificity and accuracy of this index are similar to those of resting ECG.

Real-time myocardial contrast echocardiography was found to be the most effective of all the modes of assessment undergone in predicting LVEF recovery. These results prove the usefulness of RT-MCE and are consistent with other recent papers [33, 34]. The significantly lower sensitivity (59%) and similar specificity (76%) found by Swinburn et al. [22] could be explained by a different detection technique requiring the high mechanical index and triggered imaging used or, perhaps more importantly, patient selection limited to anterior wall infarction in our study. The left anterior descending artery area is the easiest area to visualise with a contrast technique.

The worst predictor of LVEF improvement in our study was definitely the presence of reperfusional arrhythmias, showing rather infarct-related artery patency but not perfusion preservation at tissue level, as in the study by Sakuma et al. [35]. This does not seem to be of use for the prognosis of LVEF behaviour in long-term follow-up.

Recently published papers have not only addressed the issue of the best perfusion preservation prediction in the infarction area but are also trying to define algorithms combined from several indices to improve statistical power [19, 26, 30]. Logistic regression analysis found that only a history of hypertension, the maximal value of the sum of ST-segment elevations, ΔtST, MBG and preserved MCE perfusion are significant elements for a model with almost 80% correct predictions in our patients. However, there are issues that should be addressed. Firstly, patients with preserved myocardial viability assessed by RT-MCE had an almost eight times greater chance of LVEF recovery. This odds ratio dominated our model. Secondly, hypertension predicts LVEF recovery. This provocative statement cannot be explained by better perfusion in the acute phase of myocardial infarction. On the contrary, hypertension diminishes the adaptive mechanisms of the microvasculature during ischaemia. The possible explanation could be the protective endothelial effect in acute ischaemia proved for ACE inhibitors which were used before the index event by 80% of the study patients [36, 37].

Limitations

The greatest limitation, despite 10 years of development, of contrast echocardiography is a lack of standards for examination and the high percentage of studies excluded from analysis owing to images that were difficult to interpret. Semi-quantitative contrast analysis is not an objective method. In a comparison between qualitative and quantitative analysis accuracy Porter demonstrated that quantitative assessment of segmental contractility improvement prediction had a higher degree of sensitivity with a similar specificity [38]. Nevertheless, this analysis requires the use of an infusion pump for contrast agent injection and additional analysing software and dramatically prolongs the interpretation of the examination.

Conclusions

The degree of tissue perfusion after PCI in acute myocardial infarction assessed by real-time myocardial contrast echocardiography is significantly related to left ventricular ejection fraction recovery in long-term follow-up

Myocardial perfusion echocardiography had a high prognostic value for the prediction of LV global function improvement. It turned out to be the best predictor among the other angiographic, echocardiographic and electrocardiographic markers. Assessment of RT-MCE, MBG and ECG analysis should be routinely implemented for prognostic reasons in patients with acute anterior myocardial infarction.

References

1. The thrombolysis in myocardial infarction (TIMI) trial. Phase I findings. TIMI Study Group. N Engl J Med, 1985; 31: 932–936.
2. Gibson C, Cannon C, Murphy S et al. Relationship between TIMI frame count and clinical outcomes after thrombolytic administration. Thrombolysis in Myocardial Infarction (TIMI) Study group. Circulation, 1999; 99: 1945–1950.
3. Vakili B, Kaplan R, Brown D. Volume — outcome relation for physicians and hospitals performing angioplasty for acute myocardial infarction in New York state. Circulation, 2001; 104: 2171–2176.
4. Cannon C. Importance of TIMI 3 flow. Circulation, 2001; 104: 624–626.
5. Kaul S, Ito H. Microvasculature in acute myocardial ischemia: part I, Evolving concepts in pathophysiology diagnosis and treatment. Circulation, 2004; 109: 146–149.
6. Corbalan R, Larrain G, NAzzal C et al. Association of noninvasive markers of coronary artery reperfusion to assess microvascular obstruction in patients with acute myocardial infarction treated with primary angioplasty. Am J Cardiol, 2001; 88: 342–346.
7. Kloner RA, Ganote CE, Jennings RB. The "no-reflow" phenomenon after temporary coronary occlusion in the dog. J Clin Invest, 1974; 54: 1496–1508.
8. Schiller NB, Shah P, Crawford M et al. Recommendations for quantitation of the left ventricle by two-dimensional echocardiography. J Am Soc Echocardiogr, 1989; 2: 358–267.
9. Pelberg RA, Wei K, Kamiyama N et al. Potential advantage of flash echocardiography for digital subtraction of B-mode images acquired during myocardial contrast echocardiography. J Am Soc Echocardiogr, 1999; 2: 358–367.
10. Senior R. Role of myocardial contrast echocardiography in the clinical evaluation of acute myocardial infarction. Heart, 2003; 89: 1398–1400.
11. Greaves K, Dixon SR, Fejka M et al. Myocardial contrast echocardiography is superior to other known modalities for assessing myocardial reperfusion after acute myocardial infarction. Heart, 2003; 89: 139–144.
12. Van't Hof A, Liem A, Suryapranata H et al. Angiographic assessment of myocardial reperfusion in patients treated with primary angioplasty for acute myocardial infarction. Myocardial Blush Grade. Circulation, 1998; 97: 2302–2306.
13. Gibson C, Cannon C, Murphy S et al. Relationship of TIMI myocardial perfusion grade to mortality after administration of thrombolytic drugs. Circulation, 2000; 101: 125–130.
14. Clayes M, Bosmans J, Veenstra L et al. Determinants and prognostic implications of persistent ST segment elevation after primary angioplasty for acute myocardial infarction. Circulation, 1999; 99: 1972–1977.
15. Veldkamp R, Green C, Wilkins M et al. Comparison of continuous ST-segment recovery analysis with methods using static electrocardiograms for noninvasive patency assessment during acute myocardial infarction. Am J Cardiol, 1994; 73: 1069–1074.
16. Pierrard I. Assessing perfusion and function in acute myocardial infarction: how and when? Heart, 2003; 89: 701–703.
17. Ito H, Tomooka T, Sakai N et al. Lack of myocardial perfusion immediately after successful thrombolysis. A predictor of poor recovery of left ventricular function in anterior myocardial infarction. Circulation, 1992; 85: 1699–16705.
18. Rochitte C, Lima J, Bluemke D et al. Magnitude and time course of microvascular obstruction and tissue injury after acute myocardial infarction. Circulation, 1998; 98: 1006–1014.
19. Sorajja P, Gersch B, Costantini C et al. Combined prognostic utility of ST-segment recovery and myocardial blush after primary percutaneous coronary intervention in acute myocardial infarction. Eur Heart J, 2005; 26: 667–674.
20. Bax J, Poldermans D, Elhendy A et al. Sensitivity, specificity and predictive accuracies of various noninvasive techniques for detecting hibernating myocardium. Curr Probl Cardiol, 2001; 26: 141–188.
21. Bax J. Improvement of left ventricular ejection fraction, heart failure symptoms and prognosis after revascularization in patients with chronic coronary artery disease and viable myocardium detected by dobutamine stress echocardiography. J Am Coll Cardiol, 1999; 334: 163–169.
22. Swinburn J, Lahiri A, Senior R et al. Intravenous myocardial contrast echocardiography predicts recovery of dysyenergic myocardium early after acute myocardial infarction. J Am Coll Cardiol, 2001; 38: 19–25.

23. Henriques J, Zijlstra F, van't Hof A et al. Angiographic assessment of reperfusion in acute myocardial infarction by myocardial blush grade. Circulation, 2003; 107: 2115–2119.
24. Araszkiewicz A, Leśniak M, Cieśliński A. Zawał ściany przedniej leczony pierwotną angioplastyką. Angiograficzne oznaki reperfuzjii. Kardiol Pol, 2004; 60: 451–455.
25. Luca G, van't Hof A, Ottervanger J et al. Ageing, impaired myocardial perfusion, and mortality in patients with ST-segment elevation myocardial infarction treated by primary angioplasty. Eur Heart J, 2005; 26: 662–666.
26. Poli A, Fetiveau R, Vandoni P et al. Integrated analysis of myocardial blush and ST-segment elevation recovery after successful primary angioplasty. Circulation, 2002; 106: 313–318.
27. Schroder R, Dissmann R, Bruggemann T et al. Extent of early ST segment elevation resolution: a simple but strong predictor of outcome in patients with acute myocardial infarction. J Am Coll Cardiol, 1994; 24: 384–391.
28. Santoro G, Valneti R, Buonamici P et al. Relation between ST-segment changes and myocardial perfusion evaluated by myocardial contrast echocardiography in patients with acute myocardial infarction treated with direct angioplasty. Am J Cardiol, 1998; 82: 932–937.
29. Wu K, Zerhouni E, Judd R et al. Prognostic significance of microvascular obstruction by magnetic resonance imaging in patients with acute myocardial infarction. Circulation 1998; 97: 765–772.
30. Iwakura K, Ito H, Kawako S et al. Assessing myocardial perfusion with the transthoracic Doppler technique in patients with reperfused interior myocardial infarction: comparison with angiographic, enzymatic and electrocardiographic indices. Eur Heart J, 2004; 25: 1526–1533.
31. De Lemos J, Antman E, Mc Cabe C et al. ST-segment resolution and infarct related artery patency and flow after thrombolytic therapy. Am J Cardiol, 2000; 85: 299–304.
32. Moons K, Klootwijk P, Meij S et al. Continuous ST-segment monitoring associated with infarct size and left ventricular function in the GUSTO-I trial. Am Heart J, 1999; 138: 525–532.
33. Balcells E, Powers E, Lepper W et al. Detection of myocardial viability by contrast echocardiography in acute infarction predicts recovery of resting function and contractile reserve. J Am Coll Cardiol, 2003; 41: 827–833.
34. Main M, Magalski A, Chee N et al. Full-motion pulse inversion power Doppler contrast echocardiography differentiates stunning from necrosis and predicts recovery of left ventricular function after acute myocardial infection. J Am Coll Cardiol, 2001; 38: 390––394.
35. Sakuma T, Hayashi Y, Sumii K et al. Prediction of short and intermediate term prognoses of patients with acute myocardial infarction using myocardial contrast echocardiography one day after recanalization. J Am Cardiol 1998; 32: 890–897.
36. Verma S, Anderson T. Fundamentals of endothelial function for the clinical cardiologist. Circulation, 2002; 105: 546–549.
37. Mancini C. Angiotensin-converting enzyme inhibition with quinapril improves endothelial dysfunction in patients with coronary artery disease. Circulation, 1996; 94: 258–265.
38. Porter T, Oster R, Deligonul U. The clinical implications of no reflow demonstrated with intravenous perfluorocarbon containing microbubbles following restoration of thrombolysis in myocardial infarction (TIMI) 3 flow in patients with acute myocardial infarction. Am J Cardiol, 1998; 82: 1173–1177.