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Microvascular perfusion in infarcted and remote myocardium after successful primary PCI: angiographic and CMR findings

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Abstract

Objectives The aim of this study was to investigate the association between TIMI myocardial perfusion (TMP) grading acute and cardiac magnetic resonance (CMR) first-pass perfusion early and at 4 months in patients with ST-segment-elevation myocardial infarction (STEMI) treated with percutaneous coronary intervention (PCI).

Material and methods One hundred ninety-eight STEMI patients were recruited from the POSTEMI study. TMP grade was assessed after PCI; CMR was performed at day 2 and after 4 months. Signal intensity was measured on first-pass perfusion images, and a maximum contrast enhancement index (MCE) was calculated.

Results Patients with TMP grade 2-3 ($n = 108$) after PCI had significantly better EF (59 ± 10 vs. 51 ± 13, $p < 0.001$) and smaller infarct volume (12 ± 8 vs. 19 ± 12 %, $p < 0.001$) at 4 months compared with patients with TMP grade 0-1 ($n = 81$). MCE in the infarcted (MCEi) and remote myocardium (MCEr) improved from early to follow-up CMR, MCEi from 94 ± 56 to 126 ± 59, $p < 0.001$, and MCEr from 112 ± 51 to 127 ± 50, $p < 0.001$. In patients with the lowest CMR perfusion early, perfusion at 4 months remained decreased compared with the other groups, MCEi 108 ± 75 vs. 133 ± 51, $p = 0.01$, and MCEr 115 ± 41 vs. 131 ± 52, $p = 0.047$.

Conclusion TMP grade and early CMR first-pass perfusion were associated with CMR outcomes at 4 months. First-pass perfusion improved after 4 months in the infarcted and remote myocardium. However, in patients with the lowest CMR perfusion early, perfusion was still reduced after 4 months.

Key Points

- *Cardiac magnetic resonance myocardial first-pass perfusion and TMP grading after successful PCI helps to assess risk in patients with ST elevation myocardial infarction.*
- *Cardiac magnetic resonance myocardial first-pass perfusion shows that microvascular perfusion after ST elevation myocardial infarction can be impaired in both infarcted and non-infarcted myocardium.*
- *Microvascular perfusion improves over time in patients with ST elevation myocardial infarction treated with primary PCI.*

Keywords ST elevation myocardial infarction · Magnetic resonance imaging · Myocardial reperfusion · Percutaneous coronary intervention

Abbreviations

AaR	Area at risk
CMR	Cardiac magnetic resonance
ECG	Electrocardiography
EDV	End-diastolic volume
EF	Ejection fraction

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ESV	End-systolic volume
IRA	Infarct related artery
LGE	Late gadolinium enhancement
MBG	Myocardial "blush" grade
MCE	Maximum contrast enhancement index
MCEi	MCE in the infarcted myocardium
MCEr	MCE in the remote myocardium
PCI	Percutaneous coronary intervention
POSTEMI	Postconditioning in STEMI study
SI	Signal intensity
TIMI	Thrombolysis in myocardial infarction
TMP	TIMI myocardial perfusion
TTP	Time to peak contrast enhancement

Introduction

In ST elevation myocardial infarction (STEMI) patients treated with primary percutaneous coronary intervention (PCI) achieve complete restoration of the epicardial blood flow in the infarct-related artery (IRA) in the majority of cases [1, 2]. Despite adequate angiographic results, myocardial perfusion remains impaired in many patients, and outcomes are variable [1–3]. Insufficient perfusion of the microvasculature can lead to higher rates of post-infarction complications and adverse left ventricular remodeling [4]. Hence, preservation of the microvasculature plays a crucial role in STEMI patients treated with primary PCI. TIMI (thrombolysis in myocardial infarction) myocardial perfusion (TMP) grading is an easily available and cost-effective method to quantify myocardial perfusion at the end of the PCI procedure and provides important information beyond epicardial flow [5–9]. However, limited data exist on the correlation between TMP grade and cardiac magnetic resonance (CMR) outcomes.

CMR imaging with myocardial first-pass perfusion at rest is a method with high spatial resolution [5, 10] and has been shown to be more sensitive to detect microvascular obstruction compared with late gadolinium enhancement (LGE) [11, 12]. First-pass perfusion at rest is well studied in the early phase after STEMI [13–15], but less is known about the long-term time course of CMR myocardial perfusion at rest. There is also limited documentation on perfusion patterns in the remote, non-infarcted myocardium.

The aim of this study was to evaluate a cohort of PCI-treated STEMI patients, investigate the role of myocardial perfusion at angiography with TMP in the acute setting, and relate the findings to left ventricle function and infarct size after 4 months. In addition, we aimed to study the role of early CMR myocardial perfusion on risk stratification in STEMI patients. First-pass perfusion findings from early CMR were related to left ventricular function, myocardial salvage and final infarct size as well as myocardial perfusion of both the infarcted and remote non-infarcted myocardium at CMR at 4 months.

Material and methods

Study population and treatment protocol

The study population was recruited from the Postconditioning in STEMI (POSTEMI) study (ClinicalTrials.gov Po1506) [16] on patients with acute STEMI treated with PCI with or without a postconditioning procedure. The study protocol was approved by the Regional Committee for Medical Research Ethics, Southeast Norway, and all patients gave written informed consent to participate in the study.

The study protocol [16] is described in detail elsewhere, and the main results including MRI functional parameters have been published before [17]. In brief, patients with acute STEMI with symptoms of < 6 h duration, occlusion of a proximal or mid-coronary artery with TIMI flow 0 or 1 before PCI and poor collaterals to the periphery of the IRA were included. Main exclusion criteria were previous myocardial infarction, occlusion of other coronary arteries than the IRA, ongoing treatment for angina pectoris, thrombolysis given as primary reperfusion treatment, cardiogenic shock, pulmonary congestion, severe hypotension, renal failure (serum creatinine > 200 mmol/l) and general contraindication to MRI. All patients in this substudy had both CMR at 2 days and after 4 months, with diagnostic images for evaluation of first-pass perfusion. Of the 272 patients randomized in the POSTEMI trial, 198 were included in the present study (Fig. 1). Two hundred twenty patients performed early CMR. Seven patients did not have follow-up CMR; two patients died and one patient had an implantable cardioverter defibrillator (ICD). One more patient died between the 4-month and 1-year follow-up.

All patients were treated with primary PCI and received a GPIIb/IIIa inhibitor. Only in a very few exceptional cases were other stenoses treated.

TIMI myocardial perfusion grade

TMP grading in the culprit artery was assessed at the end of the PCI procedure. After intracoronary injection of 200 μg glycerol trinitrate, coronary angiography was performed in two separate projections, visualizing the periphery of the IRA. The final angiographies allowed the contrast media to both wash in and wash out of the microvasculature. TMP grades were defined according to the method of Gibson et al [18]: TMP grade 0, failure of contrast to enter the microvasculature (no blush); TMP grade 1, contrast slowly enters but fails to exit the microvasculature; TMP grade 2, delayed entry and exit of contrast from the

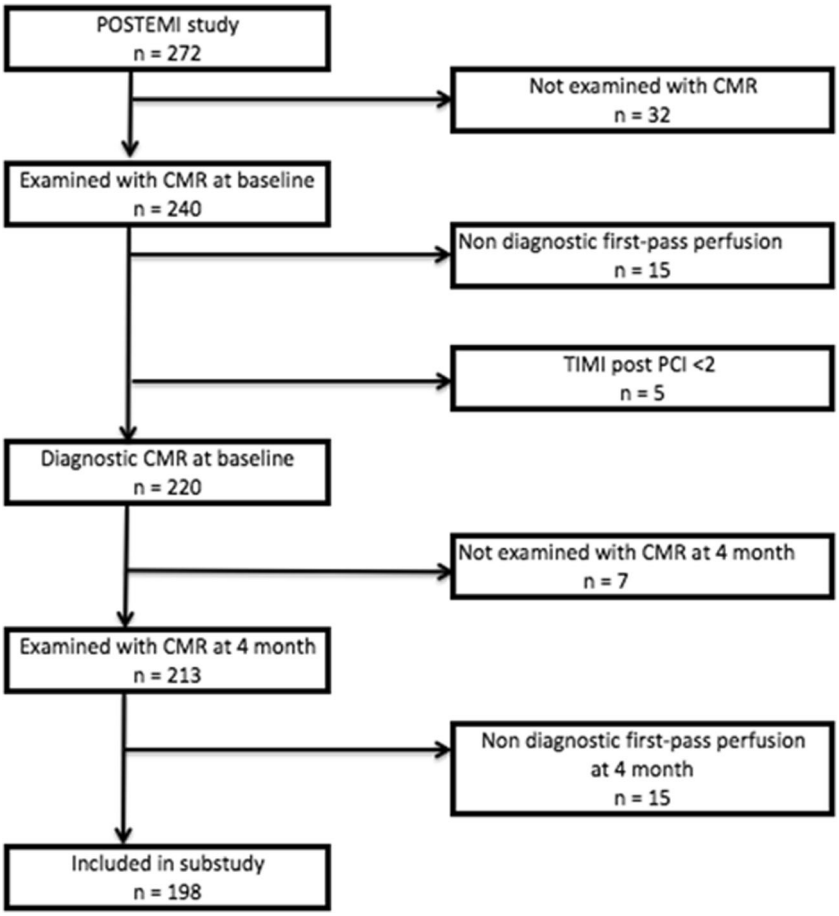

Fig. 1 Study flow chart. CMR, cardiac magnetic resonance; TIMI, thrombolysis in myocardial infarction

microvasculature; TMP grade 3, normal entry ("blush") and exit of contrast from the microvasculature.

In a previous study from our institution, interobserver reproducibility was 76% [5].

CMR protocol

CMR was performed after 2 (1-5) days and 4 (3-8) months after the STEMI on a 1.5-T scanner (Philips Intera, release 11 or Philips Achieva, release 3.2.1.1; Philips Healthcare), using a five-element synergy-cardiac coil or Sense-cardiac coil, respectively, and vector-based electrocardiography (ECG).

The left ventricle was scanned in two- and four-chamber long-axis view using balanced fast-field echo sequences for functional analysis, and short axis images were acquired for complete left ventricular volume analysis. T2-weighted imaging was performed in the cardiac short axis plane using black blood inversion recovery fast-spin echo sequences.

First-pass perfusion at rest was performed using the ECG-triggered fast T1-enhanced gradient-echo technique with segmented K-space and saturation pre-pulse. Between three and four short axis slices were acquired during breath hold, scanning for 1 min. The parameters were: TR (time to repeat) 3.2 ms, TE (time to echo) 1.26 ms, flip angle 20° and saturation prepulse delay 200 ms, trigger delay approximately 210 ms, matrix 128 and FOV (field of view) 350 mm.

The late gadolinium enhancement (LGE) study was performed 15 min after the first-pass study in short axis view, using the 3D turbo-field-echo technique with inversion prepulses, covering the whole left ventricle. The imaging parameters were: TR 4.5 ms, TE 1.44 ms, flip angle 15° and trigger delay 375-1226 ms, chosen according to the ECG RR interval to fit end-diastole.

In all patients, gadolinium-DTPA (Magnevist®. Schering AG) was injected using a Spectris power injector. For the first-pass perfusion imaging, 0.05 mmol/kg body weight was injected at the rate of 3 ml/s into the left brachial vein followed by 25 ml of saline infused at the same speed. For LGE imaging, an additional dose of 0.1 mmol/kg of Magnevist was injected 15 min before acquisition.

CMR analysis

Image analysis was performed offline on a View Forum workstation, Philips Intera extended MR workspace R2.6.3.1. (Philips Healthcare). The left ventricular ejection fraction (EF), end-diastolic volume (EDV) and end-

systolic volume (ESV) were calculated by assessment of the volumes of the endocardial contours in diastole and systole of the short axis images. The included slice closest to the mitral valve plane had myocardium in at least 2/3 of the circumference of the left ventricle. To obtain the volume of the left ventricular myocardium, epicardial tracing was performed in the diastole.

Myocardial first-pass perfusion was analyzed semiquantitatively by measuring the signal intensity (SI) versus time (Fig. 2) [19]. SI was measured with manually traced regions of interest in the area of the infarction selecting the short axis slice considered to be the most representative of the infarction and in a myocardial area remote to the infarction [5]. The infarcted region was specified from the LGE study, also including the microvascular obstruction (MVO) area. The following parameters were calculated for each region: maximum contrast enhancement index (MCE) = (maximum SI after contrast - SI at baseline)/SI at baseline ×100. Time to peak contrast enhancement (TTP) was measured from entry of the contrast medium into the left ventricle to peak myocardial SI [19].

Area at risk (AaR) was assessed in the T2 images from the early CMR, manually drawing the contour of the bright high signal region in the central three of the five short axis slices. AaR was compared with the whole area of the three slices. The size of the infarction was assessed in the LGE images. The volume of the infarction was also related to the total left ventricular myocardial volume. Myocardial salvage was defined as (AaR at early CMR - infarct size at follow-up)/AaR at early CMR ×100.

The reader was blinded to treatment strategy and clinical outcome. We have previously published the statistics from this cohort [17]. The intraobserver reliability estimated by the intraclass correlation coefficients for AaR and infarct size were 0.876, 95% CI (0.628 to 0.963) and 0.985, 95% CI (0.963 to 0.994), respectively.

Design and statistical analysis

Continuous data are presented as mean ± standard deviation; categorical data are in numbers (%).

To compare patients with different perfusion levels, MCE data of infarcted myocardium (MCEi) at the early CMR were divided into four quartiles where quartile 1 represents the highest and quartile 4 the lowest perfusion level. Likewise, patients were divided into two groups based on the TMP grade post PCI (TMP grade 0-1 and TMP grade 2-3).

One-way ANOVA or the chi-square test for categorical variables was used to compare the means of the groups.

$p < 0.05$ was considered statistically significant. Regression analysis was performed to control for effect modifiers and for quantification of confounders. IBM SPSS Statistics 24 was used.

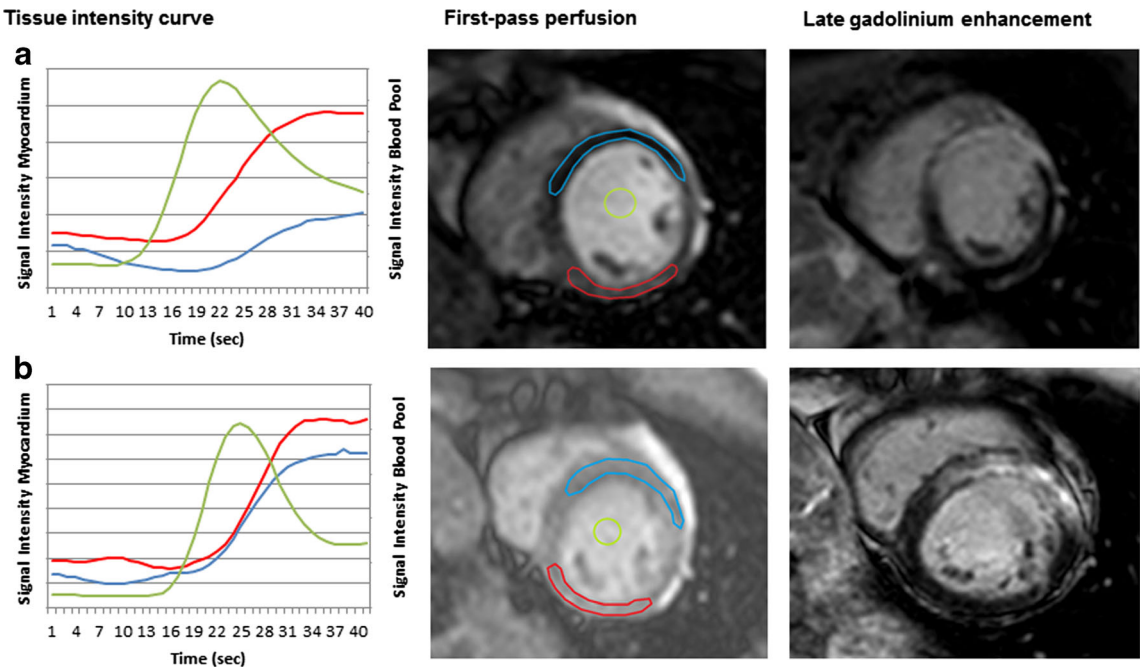

Fig. 2 Analysis of first-pass perfusion CMR. Tissue intensity curves, first-pass perfusion images with ROI and late gadolinium enhancement sequences of a patient with left anterior descending infarction early (**a**) and at 4-months follow-up (**b**). (**a**) Decreased perfusion in the infarcted anteroseptal myocardium compared with the remote area. (**b**) The difference between perfusion of the infarcted and remote myocardium has decreased. Green line: ROI blood pool in the left ventricle; blue line: ROI infarcted myocardium; red line: ROI remote myocardium. Because of the different magnitude of the signal in the blood pool and myocardium, a secondary vertical axis was implemented.

Results

Baseline characteristics of the 198 patients included in this substudy are shown in Table 1. There were no significant differences between the two treatment groups except for patient age (standard treatment 58.5 ± 10.3 years; postconditioning 62 ± 11 years, p = 0.022). The results on TMP grade and CMR first-pass perfusion at rest (early and follow-up) showed no significant differences between patients treated with PCI with or without postconditioning.

When patients were divided into four quartiles of MCEi from early CMR (2 days post STEMI), patients with high MCEi had significantly better perfusion parameters, functional parameters, smaller infarct sizes and better myocardial salvage at CMR at 4 months compared with patients with low MCEi (Table 2). The differences were significant also when controlled for confounders (age, sex, treatment for dyslipidemia, diabetes or hypertension, smoking status, symptom-to-balloon time and IRA), data not shown.

Both MCEi and MCEr improved from early to follow-up CMR (Fig. 3a and b). However, patients with the lowest perfusion at early CMR had significantly more reduction in MCE in the infarcted area at follow-up, MCEi 133 ± 51 vs. 108 ± 75, p = 0.01, and in the remote area, MCEr 131 ± 52 vs. 115 ± 41, p = 0.047) compared with the other groups.

TMP grading was performed in 95% of the patients; 81(41 %) of the patients had TMP grade 0-1. Patients with TMP grade 0-1 had significantly lower MCEi in the early phase compared with patients with TMP grade 2-3 (Table 3). Patients with TMP grade 2-3 had significantly better outcome at CMR at 4 months compared with patients with TMP grade 0-1. However, correlation between TMP grade and MCEi at 4 months was not significant (TMP 0-1: MCEi 122 ± 65; TMP 2-3: MCEi 132 ± 54, p = 0.257).

Table 1 Baseline characteristics

n = 198		
Female		35 (18)
Age, years		60 ± 11
Symptom-to-balloon time, min		195 ± 86
Door-to-balloon time, min		34 ± 11
Treated hypertension		56 (28)
Treated dyslipidemia		19 (9.6)
Current and former smoking		130 (66)
Treated diabetes		12 (6)
Thrombectomy		45 (23)
Infarct-related artery	LAD	94 (48)
	CX	22 (11)
	RCA	82 (41)
1 vessel disease		134 (68)
2 vessel disease		39 (20)
3 vessel disease		25 (13)
Peak troponin T, ng/l		7007 ± 5519

Discussion

CMR first-pass perfusion

The main findings of the present study were that MCEi short time after STEMI is a validated parameter to improve risk stratification, as it was associated with CMR outcome at 4 months. The results confirm findings in several previous studies [14, 20]. For instance, Ørn et al [21] showed that microvascular obstruction on CMR first-pass perfusion at 1 week was an independent predictor of infarct size at 1-year follow-up. Nijveldt et al demonstrated an association of impaired first-pass perfusion with increased left ventricular volumes and decreased left ventricular EF at 4-month follow-up [15].

Limited data are available on first-pass perfusion at follow-up. In the present study, no significant difference was shown between MCEi and MCEr at 4 months, which is in accordance with Ørn et al, who found no difference in visual assessment of first-pass perfusion between infarcted and remote myocardium at 2 months and 1 year [21]. Noël et al described restored microvascular perfusion in the infarcted myocardium at CMR first-pass perfusion 3 weeks after STEMI [22]. There are few studies on quantitative evaluation of first-pass perfusion at follow-up. Visual analysis of first-pass perfusion images depends on the relative difference between infarcted and remote myocardium. To detect alterations in both the infarcted and remote myocardium, the use of quantitative and semiquantitative analysis can overcome this problem. Hopp et al [10] found consistent differences between infarcted and remote tissue in the quantitative analysis of kinetic first-pass perfusion parameters but no significant changes over time from baseline to follow-up at 6 months. In contrast, the present study revealed improvement of the perfusion level for the majority of patients in both infarcted and remote myocardium. However, even though they improved from early CMR to follow-up, patients with the lowest tissue-level perfusion in the infarcted myocardium at early CMR still had diminished MCEi and MCEr at follow-up compared with the other groups, even when controlled for confounders. The mechanisms behind these changes in the remote myocardium are still ambiguous. It is assumed that regulation mechanisms of the microvasculature [23, 24] and inflammatory responses post-infarction play a major role [25].

However, a histology study on humans with large infarctions identified apoptosis in the AaR (ca. 12%) and in the remote myocardium (ca. 1%) [26]. A similar finding of necrosis in the remote myocardium was made in animal studies

Table 2 CMR data at 4 months according to quartiles of MCE of the infarcted myocardium at the early CMR

Quartiles of MCEi at early CMR	1	2	3	4	*p* value
n	49	50	50	49	
MCE infarcted myocardium	153 ± 59	130 ± 39	115 ± 47	108 ±75	0.001
MCE remote myocardium	149 ± 59	129 ± 42	116 ± 50	115 ± 41	0.001
TTP infarcted myocardium	14.1 ± 3.7	15.1 ± 3.3	14.8 ± 3.7	16.7 ± 4	0.011
TTP remote myocardium	13.7 ± 3.8	14 ± 3.2	14 ± 3.9	15.7 ± 4.1	0.046
EDV	152 ± 34	177 ± 49	190 ± 60	194 ± 45	< 0.001
ESV	63 ± 30	78 ± 45	93 ± 54	97 ± 38	< 0.001
EF	59 ± 10	58 ± 12	54 ± 13	51 ±10	0.002
Total infarct volume	12 ± 11	17 ± 15	23 ± 19	27 ± 16	< 0.001
Relative infarct volume (% of left ventricle)	11 ± 9.2	14 ± 10	17 ± 12	19 ± 11	0.003
Myocardial salvage	63 ± 23	57 ± 24	49 ± 18	44 ± 22	0.001

Data are presented as mean ± standard deviation. *p* values indicate the level of significance among the four quartiles.

MCE, maximum contrast enhancement; TTP, time to peak enhancement; EDV, end-diastolic volume; ESV, end-systolic volume; EF, ejection fraction; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery

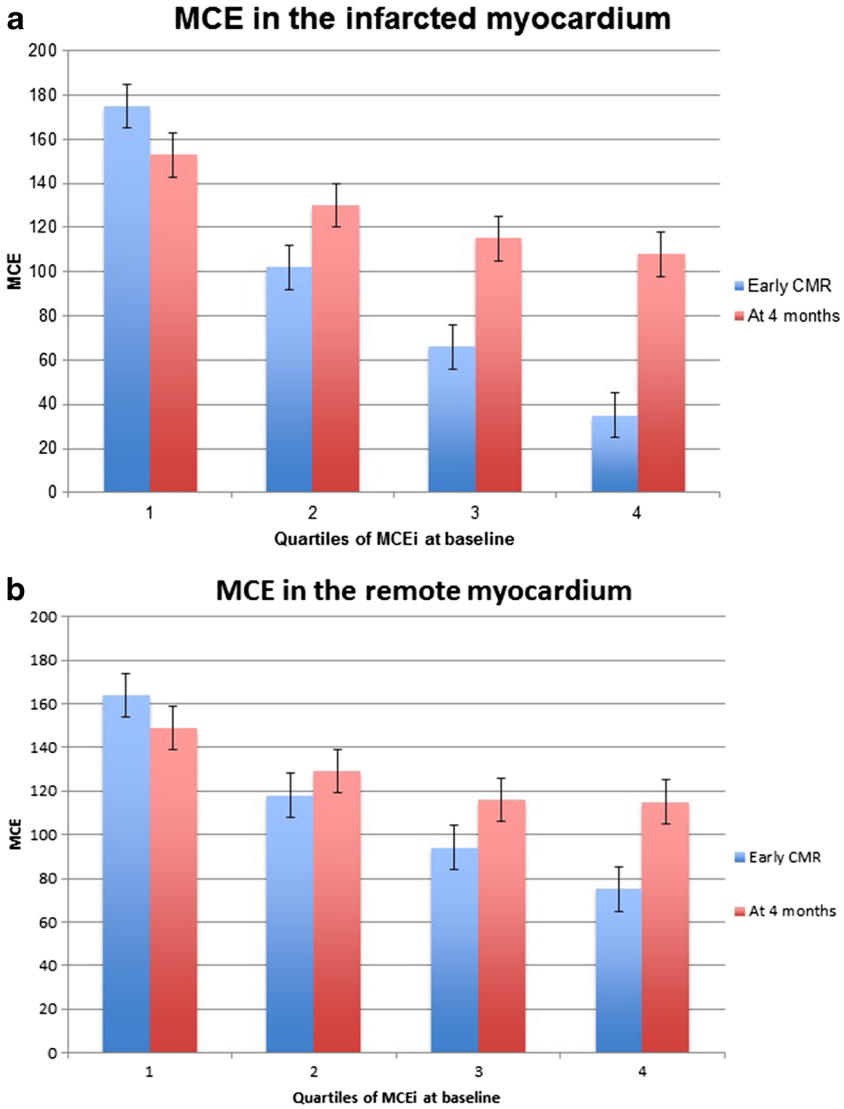

Fig. 3 (**a**) Change in MCE in the infarcted myocardium between the early CMR to the follow-up CMR. (**b**) Change in MCE in the remote myocardium between the early CMR to the follow-up CMR. MCE, maximum contrast enhancement index

Table 3 TIMI myocardial perfusion, early CMR first-pass perfusion and CMR findings at 4 months

	TMP 2-3	TMP 0-1	*p* value
n	108	81	
Data early CMR			
MCE infarcted myocardium	102 ± 58	85 ± 53	0.042
MCE remote myocardium	115 ± 53	111 ± 49	0.610
Data follow-up CMR			
MCE infarcted myocardium	132 ± 54	122 ± 65	0.257
MCE remote myocardium	133 ± 56	119 ± 39	0.064
TTP infarcted myocardium	14.3 ± 3.5	16.4 ± 3.8	< 0.001
TTP remote myocardium	13.8 ± 3.9	15.2 ± 3.7	0.016
EDV	170 ± 47	187 ± 56	0.022
ESV	72 ± 35	96 ± 52	< 0.001
EF	59 ± 10	51 ± 13	< 0.001
Total infarct volume	15 ± 13	26 ± 19	< 0.001
Relative infarct volume, (% of left ventricle)	12 ± 8.1	19 ± 12	< 0.001
Myocardial salvage	53 ± 23	45 ± 21	< 0.001

Data are presented as mean ± standard deviation or *n* (%). TMP, TIMI myocardial perfusion; TTP, time to peak enhancement; MCE, maximum contrast enhancement index; EDV, end-diastolic volume; ESV, end-systolic volume; EF, ejection fraction

[27–29]. A recent study on T1 mapping of the remote myocardium after STEMI revealed persistently (over 6 months) elevated extracellular volume (ECV) in patients with large myocardial infarctions. The authors assume underlying replacement fibrosis and left ventricular remodeling rather than edema, as they could not show an association with T2 values [30]. As they did not find an association between the number of vessels with stenosis and ECV in the remote myocardium, they rejected ischemia as a component in remodeling of the remote myocardium. In another study, native T1 mapping of the remote myocardium was an independent predictor of MACE and added important diagnostic information to the more established CMR parameters like EF [31].

MVO depicted on LGE is regarded as the gold standard to predict left ventricular remodeling. However, first-pass perfusion is more sensitive compared with LGE, and it is assumed that diffusion of the contrast media into the myocardium leads to fewer cases of MVO on LGE [15]. In contrast to MVO and infarct size on LGE, MCE measures the degree of the perfusion deficit rather than the volume of the myocardium affected. The present study shows that even small changes in the infarcted and remote myocardium can be detected with CMR first-pass perfusion. These findings may potentially contribute in a multiparametric CMR approach to identify patients at increased risk for left ventricular remodeling who may benefit from more tailored treatment. More research on CMR first-pass perfusion at rest in STEMI patients is needed to evaluate the relationship to clinical and long-term outcomes and the information that is added to established CMR parameters.

TMP grade

TIMI flow grade 3 is achieved in a great majority of STEMI patients treated with PCI [1, 2]. Hence, there is an additional demand for evaluating the microvasculature in the acute setting. Recent research indicates that invasive, guidewire-based methods such as the index of microvascular resistance are promising prognostic tools but were not applied in the present study, considering the acute situation after STEMI [32]. In a study by Joost et al TIMI flow before PCI was identified as an independent predictor for CMR-derived infarct size, MVO and myocardial salvage [33]. The present study focuses on TMP grade in the IRA post-PCI procedure. As well documented earlier [5, 9, 34, 35], also in the present study the TMP grade post-procedure was associated with functional CMR parameters and total and relative infarct size at 4 months after STEMI. Good myocardial perfusion assessed by angiography post PCI has also repeatedly been shown to be related to improved survival [1, 6, 36]. It may be discussed whether it is correct to regard TMP grade 2 as reestablished perfusion comparable to grade 3 [1, 18]. As in previous studies from our institution [9] and by others [34, 37], dividing patients into two TMP groups was chosen for the present study.

TMP grade and CMR first-pass perfusion

TMP grade post procedure is associated with first-pass perfusion at early CMR but not at 4 months. These findings are in accordance with recent findings from our institution on STEMI patients at CMR at 3 months [9]. It is an ongoing discussion whether angiographic perfusion parameters and

CMR first-pass perfusion reflect the same aspect of myocardial physiology and pathology after STEMI treated with PCI. Nijveldt et al [3] for example did not find a significant correlation between myocardial "blush" grade (MBG), a similar angiographic perfusion parameter to TMP, and early CMR first-pass perfusion in a study including 60 patients. Porto et al [38] in contrast, demonstrated a significant relation between MBG and early CMR first-pass perfusion in a small study of 27 patients. Meanwhile, Wong et al found significant correlation between TMP but not MBG and impaired early CMR first-pass perfusion [39]. A lower grade of standardization of the angiographic perfusion parameters in terms of the volume and rate of contrast agent administration may influence the comparability of clinical trials.

Niccoli et al [40] found changes in MBG over time on repeated in-hospital coronary angiography. One year after PCI, Steigen et al demonstrated improvement in TMP grade compared with the acute phase in STEMI patients [41]. Also time delay from symptom onset to PCI has been shown to have an important impact on the predictive effect of TMP [9] and MBG [40] in STEMI patients. Change in TMP before and after PCI in patients with spontaneously reperfused STEMI and TIMI 3 flow before PCI seems to have an influence on mortality and CMR outcome at 6 months [42].

This reflects that the development of microvascular no-reflow is a dynamic and yet not fully understood process [43]. Hence, angiographic and CMR assessment of microvascular perfusion may display different stages of the process and CMR first-pass perfusion at 4 months can add valuable diagnostic information.

Limitations

In the present study, first-pass perfusion CMR covers only three slices and not the entire left ventricle, which can lead to inaccuracy [44]. Great care was taken to standardize contrast infusion, but we cannot completely exclude some variations in infusion and hemodynamics between individual patients. Because of the acute condition after STEMI treated with primary PCI, stress perfusion was not performed in the present study population even though it might correlate more strongly with the extent of early and late MVO compared with first-pass perfusion at rest [39]. Guidelines recommend stress testing within 3 to 6 weeks after the acute event in STEMI patients treated with PCI and the presence of multi-vessel disease [45]. In the present study no other stress testing than exercise ECG was performed. Moreover, first-pass perfusion at rest is widely used in studies on patients with acute STEMI [21, 22, 46, 47].

Whether TMP data should be divided into 0/1 and 2/3 or TMP grade 2 should be considered as a category of its own is controversial.

The time delay between TMP grading at angiography and CMR is a potential limitation as microvascular perfusion after infarction changes over time.

Few clinical events in this study were in accordance with the expected findings from published studies on STEMI patients treated with PCI [48, 49]. The present study was not powered to evaluate the association between perfusion parameters and clinical events.

Conclusion

Both TMP grade after the primary PCI and early CMR first-pass perfusion were associated with CMR outcomes of global function of the left ventricle at 4 months. After 4 months first-pass perfusion was improved in both infarcted and remote myocardium, and there was no longer any significant difference between infarcted and remote myocardium. However, in patients with the lowest perfusion at the early CMR, first-pass perfusion was still reduced in both infarcted and remote myocardium after 4 months.

MCE is a sensitive parameter with the potential to optimize risk stratification beyond the standard angiographic and CMR parameters. In clinical studies evaluating new treatments, first-pass perfusion and MCE can discriminate small effects and in this way may contribute to the reduction of the number of patients needed in a study population. In the future, new approaches targeting the remote myocardium will potentially need imaging methods to detect alteration not only in the infarcted but also the remote myocardium.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Pavel Hoffmann.

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry One of the authors, David Swanson, has significant statistical expertise.

Informed consent Written informed consent was obtained from all subjects (patients) in this study.

Ethical approval Institutional Review Board approval was obtained.

Study subjects or cohorts overlap Several articles on the cohort of patients included in the POSTEMI trial have been published [1-5]. The results reported were mainly clinical and biochemical endpoints. CMR results reported were infarct size, left ventricular function, microvascular obstruction, area at risk and myocardial salvage. Data on CMR first-pass perfusion have not been published yet.

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Methodology
- prospective
- randomized controlled trial
- performed at one institution

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