# Collateral function changes during primary percutaneous coronary intervention in acute myocardial infarction

## Effect on infarct size

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## Summary

*Background:* This study in patients undergoing primary percutaneous coronary intervention (PCI) for acute myocardial infarction sought to test the hypotheses that collateral flow index (CFI) is reduced after unprotected recanalisation, or unaltered with protected PCI, and that collateral flow is related to infarct size.

*Methods and results:* 46 patients (age 63 ± 12 years, 36 men, 10 women) with acute myocardial infarction underwent primary PCI of the occluded culprit vessel. Coronary collateral degree was assessed angiographically (score 0–3) before recanalisation of the occlusion. A sensor guide wire (Doppler or pressure sensor) was used for PCI to obtain CFI during the first two balloon occlusions. The study population was divided into two groups depending on the use of a coronary distal embolisation protection device (without protection device: n = 29, with protection device: n = 17). Infarct size was determined using serial serum creatine phosphokinase (CK) measurements up to 24 hours after PCI. There was an inverse relation between angiographic coronary collateral degree as obtained before PCI and peak CK level. In the group without but not with protection device, however, there was a trend to a *direct* relation between CFI and peak CK level. The CFI change between the 1st and 2nd balloon occlusions was –0.032 in the group without a protection device (p = 0.049), and +0.002 in the group with a protection device (p = 0.73).

*Conclusion:* In patients with acute myocardial infarction, collateral function becomes impaired following primary PCI in the absence but not in the presence of a distal coronary embolisation protection device. Coronary collateral degree obtained prior to PCI, but not collateral function determined during PCI, is inversely predictive of infarct size. Our study indicates that the latter is probably related to the fact that pressure-derived CFI in acute myocardial infarction reflects elevated left ventricular filling pressure rather than collateral function.

*Key words: primary percutaneous coronary intervention; acute myocardial infarction*

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## Introduction

Annual mortality from cardiovascular causes across Europe is 5.4 deaths per 1000 inhabitants (49% of all deaths), and 2.4 deaths per 1000 inhabitants are due to ischaemic heart disease (22%) [1]. In patients suffering from coronary artery disease (CAD), the *size* of the myocardial infarction is the most important determinant of outcome after this event [2]. Accordingly, a primary therapeutic strategy is to reduce cardiovascular mortality by shrinking infarct size (IS). IS increases with coronary occlusion time, myocardial area at risk of infarction (AR), lack of collateral supply, absence of preconditioning and myocardial demand for oxygen [3].

Studies in patients with chronic total coronary artery occlusion have shown that a substantial fraction of collateral flow is lost immediately after recanalisation [4, 5]. It has been speculated that the phenomenon described is due to reduced demand for collateral supply to the collateral-receiving region, to vasoconstrictive substances being released through the intervention or to thrombotic material becoming mobilised by the intervention to embolise into the downstream cir-

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culation [6]. So far there has been no comparable investigation into the instantaneous behaviour of collateral function in patients with acute myocardial infarction undergoing primary percutaneous coronary intervention (PCI), nor has the effect of changes in collateral function on infarct size been studied in this setting. The use of a distal microcirculatory embolisation protection device on the theorised alterations in coronary collateral function has not been investigated either.

Thus the present study in patients undergoing primary PCI for acute myocardial infarction sought to test the hypotheses that collateral flow index (CFI) is reduced following unprotected recanalisation, or unaltered with protected PCI, and that collateral flow is related to infarct size.

## Methods

### Patients and procedure prior to PCI

Individuals eligible for enrolment in the study were patients aged ≥18 years with acute myocardial infarction presenting more than 30 minutes and less than 24 hours after symptom onset, with ≥2 mm ST-segment elevation in ≥2 contiguous leads or with presumably new left bundle-branch block, in whom primary PCI was intended. Exclusion criteria were major surgery or active bleeding within the previous 6 weeks, allergy to acetylsalicylic acid, heparin or abciximab, neutropenia, thrombocytopenia, hepatic dysfunction, renal insufficiency and cardiogenic shock. Treatment in the emergency department before PCI included acetylsalicylic acid (500 mg IV), heparin (5000 U IV), clopidogrel (300 mg PO), and beta-blockers.

46 patients (age 63 ± 12 years, 36 men, 10 women) with one- to three-vessel CAD were included in the study. All underwent primary PCI of the occluded culprit vessel. The study population was divided into two groups according to the use of a coronary distal embolisation protection device (PercuSurge GuardWire®, Medtronic Corp, Santa Rosa, CA, USA); or without a protection device: n = 29, with a protection device: n = 17). All 20 patients treated after the introduction of the protection device to our laboratory (April 2002) were randomly assigned to the groups with or without a protection device. The present investigation was approved by the institutional ethics committee and the patients gave written informed consent to participation in the study.

### Coronary angiography and primary PCI

Patients underwent left heart catheterisation for diagnostic purposes via the right femoral artery approach. Biplane left ventriculography was performed followed by diagnostic coronary angiography. The latter included angiographic assessment of coronary collateralisation to the occluded artery (see below). Central venous pressure (CVP) was measured via the right femoral vein. Following identification of the culprit lesion, 5000 U heparin and abciximab (0.25 mg/kg IV bolus and 0.125 µg/kg/min as infusion) were given to all patients, and primary PCI was begun using 8 French guiding catheters. Recanalisation of the coronary occlusion was performed using the sensor guide wire (later employed for functional collateral assessment) together with the PercuSurge® guide wire in the group a with protection device (see also below). The first two vessel occlusions with appropriately sized angioplasty balloons were done as part of primary PCI with functional collateral assessment (see below), but before placing a stent. Later, the culprit lesion was treated using stents in all patients.

### Embolisation protection device

The distal embolisation protection device consisted of a 0.014-inch guidewire incorporating a central inflation lumen distally attached to an elastomeric balloon (0.028-inch in cross-section profile, 2–5 mm diameter range) which when inflated resulted in cessation of antegrade blood flow. Intervention was performed via the sensor wire which was placed more distally than the tip of the embolisation protection wire. Debris liberated by the PCI procedure and suspended within a stagnant blood column was aspirated through a 5 French monorail export catheter. The elastomeric protection balloon was placed as close to the lesion as possible to minimise exposure of unprotected side branches to embolic debris. The first and third or later angioplasty balloon inflations were protected in the group with embolisation protection (any debris was aspirated before inactivation of the protection system) but the second inflation was not, thus making it possible to determine on an exclusive basis the effect of protecting the first occlusion.

### Coronary collateral assessment

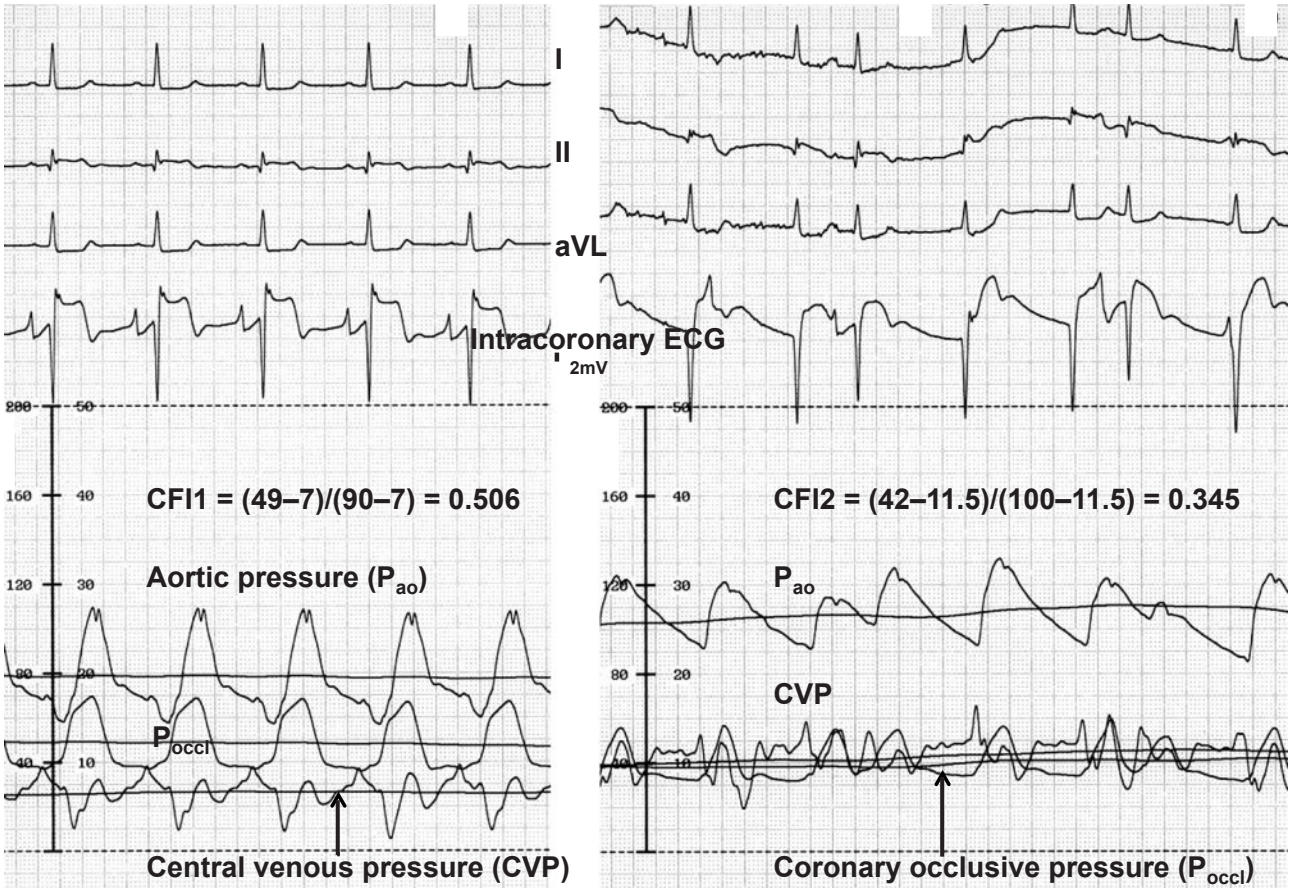
#### Angiographic collateral assessment

Angiographic collateral degrees (0–3) were determined according to the extent of epicardial coronary artery filling of the occluded vessel via collaterals with contrast medium from the contralateral side before PCI: 0 = no filling of the vessel via collaterals; 1 = small side branches filled; 2 = major side branches of the main epicardial vessel filled; 3 = main epicardial vessel filled by collaterals [7]. Angiographic assessment was performed offline by an observer unaware of the Doppler or pressure wire results.

#### Sensor-derived collateral measurements [8, 9]

In all study patients, recruitable coronary collateral flow during the different vascular balloon occlusions relative to normal antegrade flow through the non-occluded coronary artery (CFI, no unit) was determined using intracoronary velocity or pressure measurements. Doppler-derived CFI was validated in comparison with pressure-derived CFI and ECG signs of isch-

**Figure 1**
Determination of pressure-derived collateral flow index (CFI) in a patient of the group with embolisation protection device (proximal occlusion of the right coronary artery). The left side of the figure shows the simultaneously obtained phasic and mean aortic ($P_{ao}$, mm Hg; scale 0–200), distal coronary occlusive ($P_{occl}$, mm Hg; scale 0–200) and central venous pressure (CVP, mm Hg; scale 0–50) during the first balloon occlusion (CFI1). The surface ECG lead II and the intracoronary ECG lead show ST segment elevations which are diminishing from the first (left side) to the second (right side; CFI2) coronary balloon occlusion. CFI is calculated by dividing distal mean coronary occlusive pressure ($P_{occl}$, mm Hg) minus central venous pressure (CVP, mm Hg) by mean aortic pressure ($P_{ao}$, mm Hg) minus CVP.




aemia [9]. Compared with velocity-derived measurements of CFI, the standard error of estimate using pressure measurements was 0.08 [9]. In patients with chronic CAD, pressure-derived CFI measurements have been found to be very accurate in comparison to simultaneous contrast echocardiographic measurements of collateral myocardial perfusion [10].

Intracoronary Doppler measurements were performed using a 0.014-inch 20-MHz Doppler crystal-tipped angioplasty guide wire (FloWire®, Volcano Therapeutics, Belgium). The Doppler guide wire was positioned distal to the occlusion treated by PCI and CFI was determined as the ratio of coronary occlusive average peak flow velocity ($V_{occl}$, cm/s) to the velocity at an identical wire position after PCI and cessation of reactive hyperaemia ($V_{Ø–occl}$, cm/s): $CFI = V_{occl} / V_{Ø–occl}$. Alternatively, a 0.014-inch fiberoptic pressure monitoring wire (Wavewire®, Volcano Therapeutics, Belgium) was set at zero, calibrated, advanced through the guiding catheter, and positioned distal to the occlusion to be treated. The pressure-derived collateral flow index was determined by simultaneous measurement of mean central venous pressure (CVP, mm Hg), mean aortic pressure ($P_{ao}$, mm Hg, via the angioplasty guiding catheter) and mean distal coronary occlusive pressure ($P_{occl}$, mm Hg) [9]. $CFI = (P_{occl} – CVP) / (P_{ao} – CVP)$ (fig. 1).

### Quantification of occlusion site: proximity index

Since infarct size is partly dependent on the ischaemic myocardial area at risk, a quantitative measure of the proximity of the lesion treated by PCI was determined by offline analysis as the ratio of the summed coronary artery branch lengths distal to the recanalized occlusion site divided by the summed branch lengths of the entire respective coronary artery [11]. This angiographic technique for the assessment of myocardial area at risk has been experimentally validated, and is independent of the number of coronary branch generations analysed beyond generation number 3 [11].

### Post-PCI management

Cardiac creatine phosphokinase enzyme (CK) and MB isoenzyme as well as troponine I levels were measured

at 0, 6, 12, 18 and 24 hours post-procedure. Pre-specified post-procedural medications consisted of acetylsalicylic acid 100 mg daily, clopidogrel 75 mg daily for 3–6 months, oral beta-blockers, angiotensin converting enzyme inhibitors and statins.

**Table 1**
Patient characteristics and clinical data at baseline.

| | No protection device (n = 29) | Protection device (n = 17) | p |
|---|---|---|---|
| Age (years) | 62 ± 12 | 64 ± 12 | 0.48 |
| Male gender | 22 | 14 | 0.95 |
| Body Mass Index (kg/m$^2$) | 26 ± 4 | 24 ± 3 | 0.29 |
| Onset of angina pectoris before PCI (hours) | 10 ± 8 | 11 ± 8 | 0.72 |
| Smoking | 17 | 5 | 0.07 |
| Hypercholesterolaemia | 14 | 6 | 0.30 |
| Hypertension | 12 | 11 | 0.13 |
| Obesity | 6 | 3 | 0.33 |
| Family history of CAD | 11 | 5 | 0.56 |
| Diabetes mellitus | 6 | 2 | 0.19 |
| Acetylsalicylic acid | 12 | 5 | 0.42 |
| β-blockers | 4 | 6 | 0.09 |
| Calcium antagonists | 2 | 0 | 0.27 |
| Nitrates | 7 | 2 | 0.27 |
| Angiotensin converting enzyme inhibitor | 3 | 3 | 0.48 |
| Statin | 4 | 2 | 0.84 |
| Diuretics | 3 | 1 | 0.60 |

CAD = coronary artery disease; PCI = percutaneous coronary intervention.

**Table 2**
Coronary angiographic data.

| | No protection device (n = 29) | Protection device (n = 17) | p |
|---|---|---|---|
| Number of vessels diseased | | | 0.54 |
| 1 | 13 | 9 | |
| 2 | 11 | 7 | |
| 3 | 5 | 1 | |
| | | | |
| Vessel undergoing PCI | | | 0.83 |
| Left anterior descending coronary artery | 12 | 8 | |
| Left circumflex coronary artery | 2 | 2 | |
| Right coronary artery | 15 | 7 | |
| Site of stenosis | | | 0.14 |
| Proximal segment | 14 | 13 | |
| Mid segment | 11 | 4 | |
| Distal segment | 4 | 0 | |
| * Proximity of the stenosis | 77 ± 14 | 79 ± 12 | 0.57 |

*: i.e., area at risk of myocardial infarction determined for each of the three main coronary arteries.
LCA = left coronary artery; PCI = percutaneous coronary intervention;
RCA = right coronary artery.

## Statistical analysis

Between-group comparisons of continuous demographic, haemodynamic, angiographic, and collateral flow data were performed by a two-sided unpaired Student's t-test. A chi$^2$-test (2 × 2 table) was used for comparison of categorical variables among the study groups. A 2-way ANOVA test for repeated measures was used for intra-individual changes of cardiac enzymes during follow-up after PCI. Possible correlations between different timepoints were taken into account by adjusting the significance level according to a Bonferroni correction ($p < 0.01$). Multiple regression analyses were performed with peak CK and CKMB enzyme levels as the dependent variables and age, left ventricular end-diastolic pressure prior to PCI, number of vessels diseased, onset of angina pectoris, angiographic collateral degree, CFI, group association, and the coronary occlusion proximity as independent variables. Mean values ± standard deviation are given unless otherwise indicated.

## Results

### Patient characteristics and clinical data at baseline

There were no statistically significant differences between the two groups regarding age, gender, Body Mass Index, onset of angina pectoris before PCI as well as the frequency of cardiovascular risk factors and use of cardiovascular drugs (table 1).

### Coronary angiographic data

The number of coronary arteries diseased and the vessel and site undergoing PCI were similarly frequent in both groups (table 2). Quantitatively, the culprit lesion location in each of the three main coronary arteries was on average 77 and 79% proximal ($p = 0.57$), respectively, in the group of patients without and with a protection device, 100% proximity indicating the ostial occlusion location (table 2).

## Haemodynamic, ventriculographic, CFI and infarct size data

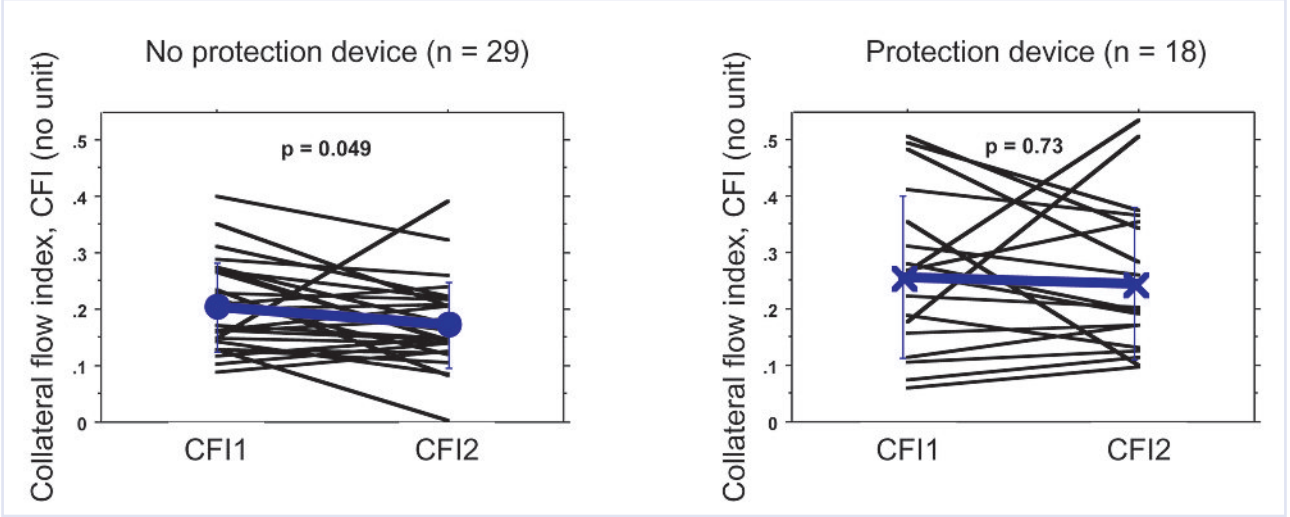
Heart rate, blood pressure and LV ejection fraction before revascularisation were similar between the groups (table 3). In the group without versus that with a protection device, LV end-diastolic pressure showed a trend towards higher values, and thee angiographic collateral degree tended to be lower. Doppler sensors for CFI measurement tended to be used more often in the group without than in that with a protection device. CFI obtained during the 1st balloon occlusion was not statistically different among the groups. CFI during the 2nd occlusion was significantly lower in the group without than with a protection device. The intra-individual CFI change between the 1st and 2nd balloon occlusions was –0.032 in the group without a protection device (p = 0.049), and +0.002 in the group with protection device (p = 0.73) (table 3 and fig. 2). Peak infarct size marker serum concentration, angioplasty balloon size, "door-to-balloon" and fluoroscopy time were not statistically different between the groups (table 3). Figure 3 demonstrates that there was an inverse relation between angiographic coronary collateral degree as obtained before PCI and peak CK level. In the group without a protection device there was a trend towards lower CK values in the course of observation in patients with CFI <0.25 and to higher CK levels in patients with CFI ≥0.25 (p = 0.0322, i.e., not significant after Bonferroni correction; fig. 4). In patients with a protection device there was no statistical difference in CK levels according to CFI (fig. 4). In the different sensor wire subgroups peak CK was inversely related to Doppler-derived CFI (peak

**Table 3**
Haemodynamic, ventriculographic, collateral circulation and infarct size data.

| | No protection device (n = 29) | Protection device (n = 17) | p |
|---|---|---|---|
| Variables obtained before revascularisation | | | |
| Heart rate (beats/min) | 76 ± 14 | 72 ± 15 | 0.38 |
| Systolic blood pressure (mm Hg) | 116 ± 16 | 117 ± 25 | 0.87 |
| Diastolic blood pressure (mm Hg) | 69 ± 11 | 73 ± 15 | 0.26 |
| LV ejection fraction (%) | 51 ± 11 | 48 ± 12 | 0.37 |
| LV end-diastolic pressure (mm Hg) | 20 ± 8 | 16 ± 8 | 0.09 |
| Angiographic collateral degree (0–3) | 1 ± 1 | 1.5 ± 1 | 0.12 |
| Variables obtained during or after revascularisation | | | |
| Doppler / pressure sensor guidewires | 16 / 13 | 6 / 11 | 0.11 |
| Collateral flow index 1, CFI1 | 0.211 ± 0.079 | 0.259 ± 0.145 | 0.18 |
| Collateral flow index 2, CFI2 | 0.179 ± 0.079 | 0.261 ± 0.134 | 0.016 |
| CFI2 minus CFI1 | –0.032 ± 0.085 | +0.002 ± 0.136 | 0.32 |
| Peak creatine phosphokinase (CK, U/l) | 2396 ± 1604 | 1818 ± 1596 | 0.24 |
| Peak CK MB isoenzyme (U/l) | 325 ± 251 | 242 ± 208 | 0.27 |
| Peak troponin I (µg/l) | 438 ± 262 | 489 ± 544 | 0.68 |
| Angioplasty balloon size (mm) | 3.1 ± 0.4 | 3.1 ± 0.3 | 0.70 |
| "Door-to-balloon" time (minutes) | 40 ± 22 | 32 ± 23 | 0.26 |
| Fluoroscopy time (minutes) | 18 ± 12 | 20 ± 7 | 0.50 |

CFI = collateral flow index; LV = left ventricular.

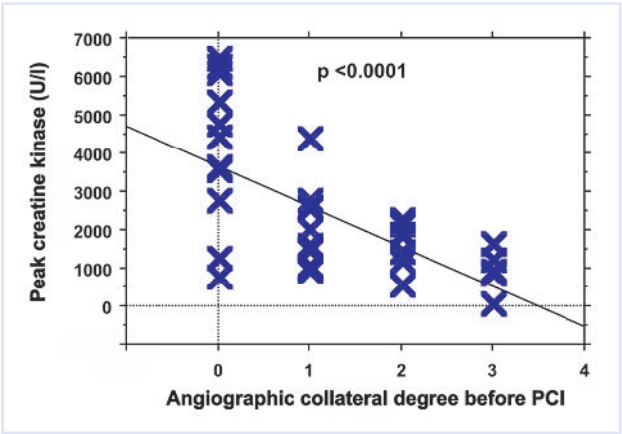
**Figure 2**
Intra-individual changes of collateral flow index between the first (CFI1) and the second coronary balloon occlusion (CFI2) following recanalisation of the lesion responsible for the acute myocardial infarction. The changes are depicted for the group without (left panel) and for that with (right panel) distal embolisation protection device. The blue symbols and lines indicate mean (± standard error) values.



CK = 3694 – 7158 CFI; r = –0.32, p = 0.05), and was directly associated with pressure-derived CFI (peak CK = 333 + 8506 CFI, r = 0.69, p = 0.004).

Using multiple regression analysis, infarct size expressed as the peak level of CK (overall p = 0.0004, $r^2$ = 0.684) and of CKMB (overall p = 0.0018, $r^2$ = 0.622) (but not troponin I), was predicted by the following variables: angiographic collateral degree (p = 0.02; inverse relation), number of vessels diseased (p = 0.03; direct relation), left ventricular end-diastolic pressure prior to PCI (p = 0.008; direct relation), and angiographic lesion proximity index (p = 0.02; direct relation).

**Figure 3**
Relation between the angiographic degree of collaterals to the occluded vessel as obtained before its recanalisation by primary percutaneous coronary intervention (horizontal axis, score 0–3) and the peak serum level of creatine phosphokinase (vertical axis).



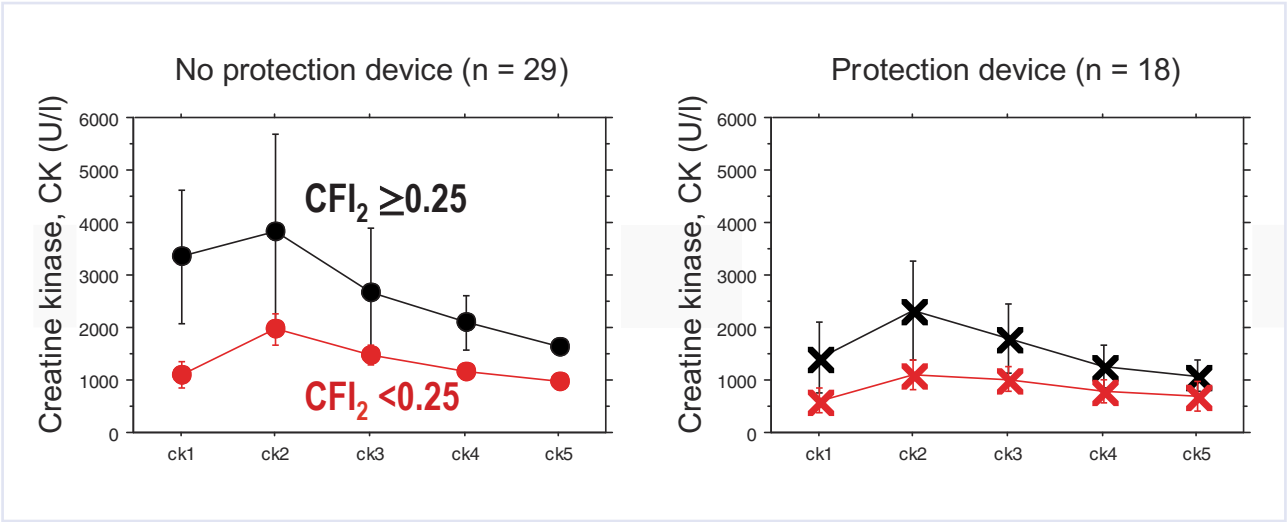

## Discussion

The novel result of this study in patients with acute myocardial infarction undergoing primary PCI is that collateral flow becomes impaired in the course of unprotected primary PCI but remains unaltered when a distal embolisation protection device is used. The latter does not appear to translate into smaller infarct size, but its well-known determinants of high pre-procedural collateral flow and small ischaemic area at risk do.

### Determinants of infarct size

Though it was not the primary goal of this study to find predictors of infarct size recognised long ago [12, 13], the confirmatory result of few angiographic collaterals and extended area at risk being related to large infarct size served as quality control for the present study's methodology. Accordingly, the question may arise whether predicting factors additionally found (number of vessels with CAD) or missing (time of occlusion, myocardial oxygen consumption) indicate study design flaws. In this context, the method of infarct size assessment by repetitive and multiple cardiac enzyme measurements can be regarded as appropriate [14]. The relevance of the expansion of CAD as a predictor is probably a statistical artefact since it reflects the size of the ischaemic area at risk or the proximity of the atherosclerotic lesion. Likewise, and on the one hand, LV filling pressure can be regarded as a false determinant since it is a direct marker of infarct size. Conversely, it is known that elevated LV diastolic pressure contributes to infarct expansion, and thus represents a real predictor [15]. That the duration of ischaemia did not foretell infarct size is probably due to the fact that

**Figure 4**
Temporal changes of average (± standard error) creatine phosphokinase (CK) serum levels in patients without (left panel) and with (right panel) a distal embolisation protection device. CK values were determined every 6 hours from the time of recanalisation of the culprit lesion to 24 hours after the procedure (horizontal axis, ck1 to ck5). The values shown are divided in a subgroup of patients with sensor-derived collateral flow index insufficient ($CFI_2$ <0.25; red symbols and lines) and sufficient ($CFI_2$ ≥0.25; black symbols and lines) to prevent myocardial ischaemia during the second 1-minute coronary balloon occlusion. See text for statistical significances.



one-third of the patients had had ischaemia for between 12 and 24 hours, the timeframe for which an association with infarct size no longer exists, thereby obscuring any correlation that exists for the previous window. Furthermore, there has been evidence showing that in the presence of well-developed collateral vessels ($^1/_3$ of our patients) the duration of coronary artery occlusion no longer influences infarct expansion [16]. Why measures for myocardial oxygen consumption did not figure as determinants for infarct size in the present study is probably related to the fact that usually they were not obtained during early arterial occlusion but only after full infarct evolution. Much closer to the main focus of the study (instantaneous collateral function changes during primary PCI) than the latter issue is the question why the invasively measured first as well as second CFI values were not independently and inversely associated with infarct size, and why in the case of unprotected primary PCI large infarcts even tended to be predicted by high values of CFI (see also fig. 4).

## Determinants of collateral flow before and during primary PCI

In the context described, it seems obvious that collateral flow around PCI for acute myocardial infarction depends on how it is determined: by angiography or interventional sensor technology. Thus, the question has been raised whether CFI obtained during acute myocardial infarction signifies something different from collateral flow, namely microvascular dysfunction [17]. On the other hand, the fall in CFI among our patients with unprotected primary PCI argues against a direct relation of CFI to microvascular dysfunction. The subsequent discussion focuses on this controversial issue.

During the chronic phase of CAD, Doppler- or pressure-derived CFI measurements have been extensively attested as accurately reflecting coronary collateral flow [9, 18]. Very recently, quantitative myocardial contrast echocardiography simultaneously performed with invasive collateral assessment in patients with chronic CAD has shown excellent agreement between the two methods [10]. Determinants of CFI in chronic CAD are the degree of the stenotic lesion of the collateralised vessel (i.e., the perfusion pressure gradient between the artery supplying and receiving the collaterals), and, probably, the degree to which collateral arterioles are preformed before manifestation of the disease [19, 20]. During or immediately following recanalisation of a chronic total coronary occlusion, collateral flow diminishes considerably, a fact which has been ascribed to the falling pressure gradient across the collateral circulation, to the release of vaso-constrictive mediators by recanalisation, and to embolisation of collateral arteries by the intervention [4, 5]. However, most of the explanations on the mechanism of the fall in CFI in recanalised chronic occlusions have remained speculative. The present study on recanalisation of *acutely* occluded coronary arteries not only provides evidence of a decline in CFI during unprotected primary PCI, but also of collateral embolisation as an important mechanism of that decline. This is so because the group undergoing protected primary PCI presented unaltered CFI during the second as compared to the first coronary occlusion. How does the trend towards a direct rather than inverse relation between CFI and infarct size fit into the interpretative framework whereby the PCI-induced fall in CFI is prevented by an embolisation protection device? Mechanically, it could be imagined that large versus tiny collateral vessels suffer exponentially from obstruction by emboli. Since in the case of well-developed collateral arteries infarct development in the presence of coronary occlusion is much delayed, whereas it is already terminated with poor collaterals, a postponed "wave" of necrosis in the former group is conceivable. However, this model of large collaterals more vulnerable to embolisation than small ones is speculative. Alternatively, LV filling pressure directly reflecting infarct size or, rather, thinned, dysfunctional myocardium is transmurally conveyed to the epicardially located pressure sensor used for CFI measurement. Recent evidence has indicated that transmural pressure transmission may be directed both ways, depending on collateral development, i.e., in well-grown collaterals LV filling pressure during a 90-s coronary balloon occlusion increases in the absence of ECG signs of ischaemia or wall motion abnormalities [21]. In this context, the earlier controversy on whether pressure-derived CFI in acute myocardial infarction is a measure of collateral flow or of microcirculatory function may be settled as follows [16, 17, 22, 23]: in cases with poorly developed collateral flow, pressure-derived CFI signifies rather the increased LV filling pressure across the microcirculatory dysfunctional, thinned myocardial wall, whilst in cases of well-grown collaterals it reflects collateral perfusion pressure. There may even be a distinct separation between the two patterns, which is related to a phenomenon called the waterfall mechanism, indicating the transmural pressure (25–30 mm Hg) beyond which collateral flow no longer depends on vascular perfusion pressure but inversely on transmural pressure [21].

The present study's results support the interpretation referred to, since, first, there was a direct relationship between LV end-diastolic pressure and pressure-derived CFI ($r = 0.37$, $p = 0.05$), but not with Doppler-derived CFI (data not shown). Second, and more importantly, infarct size was inversely related to Doppler-derived CFI but directly associated with pressure-derived CFI.

## Study implications

For practical purposes the results of this investigation imply that collateral assessment in acute myocardial

infarction is valuable for risk stratification, but that it should be performed before and not during PCI. The usually rather blunt instrument of angiographic collateral qualification can be optimally used in acute myocardial infarction with a totally occluded culprit lesion, since this situation is a simple way of estimating recruitable collateral flow without double coronary injection [7]. With respect to coronary collaterals, the use of a distal embolisation protection device appears justified despite the fact that its efficacy has not been documented in a controlled trial including patients with primary as well as rescue PCI [24].

## Study limitations

Apart from the limitations alluded to above, it should be mentioned that scintigraphic infarct size measurements have been more precise than enzymatic. Optimally, a second angiographic collateral assessment by double injection technique at the end of PCI would have been performed to support the finding of the collateral-protecting effect of the distal embolisation protection device. The use of two different sensor wires for collateral assessment can be regarded as an advantage rather than a disadvantage of this study, because it allowed more distinctive data interpretation. Study group randomisation started only after the availability of the protection device and not from the beginning of the investigation. No study follow-up data were obtained which would afford insight into the relevance of preventing a fall in collateral flow during primary PCI with regard to recovery of ventricular wall motion abnormalities.

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