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ABSTRACT

Objectives The aim of the study was to evaluate whether primary percutaneous coronary intervention (PCI) with combined proximal embolic protection and thrombus aspiration results in smaller final infarct size and improved left ventricular function assessed by cardiovascular magnetic resonance (CMR) in ST-segment elevation myocardial infarction (STEMI) patients compared with primary PCI alone.

Background Primary PCI with the Proxis system improves immediate microvascular flow post-procedure as measured by ST-segment resolution, which could result in better outcomes.

Methods The ancillary CMR study included 206 STEMI patients who were enrolled in the PRoximal Embolic Protection in Acute myocardial infarction and Resolution of ST-Elevation (PREPARE) trial. CMR imaging was assessed between 4 and 6 months after the index procedure.

Results There were no significant differences in final infarct size (6.1 g/m^2 vs 6.3 g/m^2, $p = 0.78$) and left ventricular ejection fraction (50% vs 50%, $p = 0.46$) between both groups. Also, systolic wall thickening in the infarct area (44% vs 45%, $p = 0.93$) or the extent of transmural segments (8.3% of segments vs 8.3% of segments, $p = 0.60$) showed no significant differences. The incidence of major adverse cardiac and cerebral events at 6 months was similar in the Proxis and control group (8% vs 10%, respectively, $p = 0.43$).

Conclusions Primary PCI with combined proximal embolic protection and thrombus aspiration in STEMI patients did not result in significant differences in final infarct size or left ventricular function at follow-up CMR. In addition, there was no difference in the incidence of major adverse cardiac and cerebral events at 6 months.

Trial registration number ISRCTN71104460.

Recent studies suggest that patients with ST-segment elevation myocardial infarction (STEMI) treated with primary percutaneous coronary intervention (PCI) with thrombus aspiration compared with primary PCI alone have a significant reduction in infarct size[1] and an improved clinical outcome one year after primary PCI.[2]

In the randomised controlled PRoximal Embolic Protection in Acute myocardial infarction and Resolution of ST-segment Elevation (PREPARE) trial, patients with STEMI treated with primary PCI with combined proximal embolic protection and thrombus aspiration using the Proxis embolic protection system (St Jude Medical, St Paul, Minnesota, USA) had significantly better immediate microvascular flow measured by ST-segment resolution. ST-segment resolution was recorded with continuous ST Holter monitoring and evaluated by a blinded independent core laboratory.[3] The improved microcirculatory reperfusion within the first hours after the restoration of epicardial flow might translate into a clinically relevant smaller infarct size and preservation of left ventricular function and clinical outcomes. Cardiovascular magnetic resonance (CMR) imaging has been considered to be the gold standard for accurate assessment of final infarct size and left ventricular function,[4 5] and therefore we performed an ancillary CMR study of the PREPARE trial to determine whether combined proximal embolic protection and thrombus aspiration result in a smaller final infarct size and preservation of left ventricular function at follow-up.

METHODS

All patients included in the present ancillary study were participants of the PREPARE trial. In this multicentre, randomised, open trial, patients with STEMI were randomly assigned to primary PCI with combined proximal embolic protection and thrombus aspiration (n = 141) or primary PCI alone (n = 143). The Proxis system was used in patients randomly assigned to primary PCI with combined embolic protection and thrombus aspiration. The Proxis system is a single-operator full-length flexible catheter (6 F and 7 F guiding catheter compatible) and is based on a carbon dioxide gas (CO_2) inflation system. It was deployed proximal to the target lesion before crossing. Inflation of the sealing balloon suspends antegrade flow during the period of lesion intervention. Stagnated blood and emboli, liberated during each intervention were retrieved by gentle aspiration. Crossing of the coronary occlusion with the wire, balloon dilatation and stent placement were performed through the Proxis system and carried out under full proximal

blockade of the vessel. Aspiration and embolic protection by temporary proximal vessel occlusion were repeated during each step of the PCI procedure.[6] Results from this randomised trial have been published previously.[3] In brief, patients were eligible for inclusion in the PREPARE trial if they experienced onset of symptoms of myocardial infarction less than 6 h before presentation and had electrocardiographic evidence of persistent ST-segment elevation of at least 200 μV in two or more contiguous leads and thrombolysis in myocardial infarction (TIMI) flow grade 0 to 1 on diagnostic angiography. Exclusion criteria were: age younger than 18 years; any contraindications to the use of glycoprotein IIb/IIIa receptor antagonists; a co-existent condition associated with a limited life expectancy; previous coronary artery bypass grafting or lytics and recurrence of myocardial infarction in the same myocardial area. The primary endpoint of the PREPARE study was ST-segment resolution at 60 minutes after the last contrast injection by continuous ST Holter monitoring. In all patients, primary PCI was performed in a standard manner as previously published. Also, all reported clinical endpoints have previously been defined.[3] Clinical endpoints included the occurrence of death, spontaneous or procedural myocardial infarction, stroke and percutaneous or surgical target vessel revascularisation.

CMR protocol and data analysis

As part of the ancillary study protocol approved by our hospital's institutional review board, all patients included in the PREPARE trial were invited to participate in the ancillary CMR study. Patients were asked for written informed consent to perform a CMR scan at 4–6 months after the index procedure. The present ancillary study included all patients who received a cardiac CMR examination.

The CMR examination was performed on a 1.5 T clinical scanner (Sonato/Avanto, Siemens, Erlangen, Germany), with the patient in a supine position, using a phased array cardiac receiver coil. ECG-gated cine images were acquired using a breath-hold-segmented steady-state free precession sequence (echo time/repetition time of 1.2/3.2 ms; spatial resolution of 1.3 × 1.8 × 5 mm). Per patient short-axis views were obtained every 10 mm starting from base to apex and covering the entire left ventricle.

Late gadolinium enhancement images were obtained 10–15 minutes after the administration of a gadolinium-based contrast agent (Magnevist, Schering AG, Berlin, Germany; 0.2 mmol/kg) using a two-dimensional segmented inversion recovery gradient-echo pulse sequence (repetition time/echo time 9.6/4.4 ms, spatial resolution 1.6 × 1.3 × 5.0 mm), with slice position identical to the cine images. The inversion time was set to null the signal of viable myocardium and typically ranged from 250 to 300 ms.

All data were analysed on a separate workstation using a dedicated software package (MASS 5.1) and by one experienced investigator (JDH) who was blinded to patient data. Left ventricular volumes were determined by planimetry of all short-axis images in each patient and the left ventricular ejection fraction was calculated. The two most basal and two most distal slices were excluded for the analysis of segmental function and transmural extent of infarction, because short-axis images at these levels preclude a reliable segmental evaluation due to the presence of the left ventricle outflow tract and partial volume effect, respectively. Regional left ventricular function was assessed by systolic wall thickening in the infarct area and was calculated as previously described.[7]

The assessment of late gadolinium enhancement images and final infarct size was done as previously described (fig 1).[8] In brief, final infarct size was calculated by automatic summation of all slice volumes of hyperenhancement (signal intensity >6 SD above the mean signal intensity of remote myocardium). The extent of transmural segments was per-patient expressed as the sum of segments with greater than 75% transmural

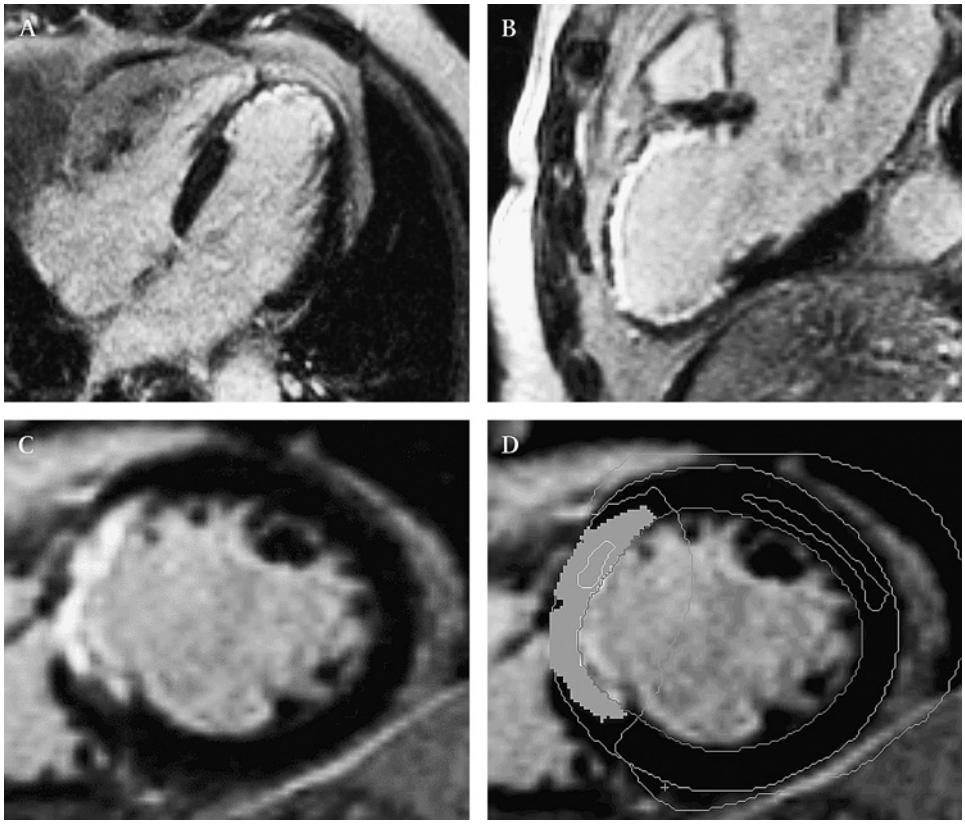

Figure 1 Late gadolinium enhancement images of a patient from the PRoximal Embolic Protection in Acute myocardial infarction and Resolution of ST-segment Elevation (PREPARE) trial with an anteroseptal myocardial infarction at 4 months. (A) Four-chamber view. (B) Three-chamber view. (C) Short-axis view. (D) Analysis of the same slice (as in the short axis view (C) after thresholding the window setting at 6 SD above the mean signal intensity of normal myocardium.

hyperenhancement as a percentage of the total number of segments scored.

Statistical analysis

Data are expressed as mean (SD) for continuous variables and as frequency with percentage for categorical variables. Comparison of CMR variables was done by the χ^2 test or by the Fisher exact test if an expected cell count was less than 5.

According to protocol, patients who had cardiac CMR examination after more than 6 months of follow-up received these CMR parameters as their imputed values. CMR values equal to the worst cardiac CMR parameters in our study population were imputed for patients who died before CMR could be obtained. With CMR data available for 200 patients (100 per group) and an α of 0.05, the study has 80% power statistically to detect differences in CMR parameters of at least 0.40 times the standard deviation. No corrections for multiple testing were applied. Statistical analysis was performed using statistical package for social sciences software (SPSS version 16.0 for Windows). A p value of less than 0.05 was considered statistically significant.

RESULTS

Patient and procedural characteristics and angiographic outcomes

Ninety-six patients randomly assigned to primary PCI with combined proximal embolic protection and thrombus aspiration and 110 patients randomly assigned to primary PCI alone were included in the ancillary CMR study. The flow chart of patients is shown in fig 2. Six months follow-up after the index procedure was available for all randomly assigned patients (n = 284). The baseline and procedural characteristics of the ancillary CMR study were equally distributed among both treatment arms, except for a higher incidence of current smoking in the control arm (table 1). As seen in table 1, the Proxis system was adequately positioned in 90 of 96 patients and no statistical differences were observed in angiographic outcomes among both arms.

CMR outcomes

CMR outcomes are listed in table 2. There were no differences in final infarct size between primary PCI with combined proximal embolic protection and thrombus aspiration and primary PCI alone (6.1 g/m^2 (SD 5.3) (95% CI 5.0 to 7.2 g/m^2) vs 6.3 g/m^2 (SD 6.1) (95% CI 5.1 to 7.5 g/m^2); p = 0.78, respectively) or in the extent of transmural segments (8.3% (SD 10.8) of segments (95% CI 6.1% of segments to 10.5% of segments) vs 8.3% (SD 12) of segments (95% CI 6.0% of segments to 10.6% of segments); p = 0.60) observed. In addition, there were no differences in left ventricular ejection function at follow-up (50% (SD 11) (95% CI 48% to 52%) vs 50% (SD 12) (95% CI 48% to 52%); p = 0.46) or in systolic wall thickening in the infarct area (44% (SD 26) (95% CI 39% to 49%) vs 45% (SD 28) (95% CI 40% to 50%); p = 0.93) between both treatment arms. A separate analysis without the six deaths did not affect the noted CMR outcomes (data not shown).

Univariable analysis showed that the use of the Proxis system did not lead to final infarct size reduction (β = 0.15, p = 0.86). In a multivariable analysis in which age greater than 65 years, diabetes mellitus, history of myocardial infarction, current smoking, multivessel disease, infarct location, symptom onset 3 h or greater, preprocedural TIMI-graded flow of 0 and treatment assignment were considered simultaneously, the effect of the Proxis system on final infarct size remained the same (β = 0.14, p = 0.86).

Subgroup analyses by infarct location, proximity of the lesion, presence of angiographic visible thrombus, duration of symptom onset to balloon, use of glycoprotein IIb/IIIa antagonists and smoking status did not reveal any subgroup with a substantial difference in final infarct size with the Proxis system (data not shown).

Six-month clinical outcomes

As seen in table 3, overall major adverse cardiac and cerebral events at 6 months occurred with similar frequency with or without combined proximal embolic protection and thrombus aspiration. Two patients in the Proxis arm died of progressive heart failure. Four patients in the control arm died of stroke (n = 1), malignancy (n = 1) and progressive heart failure (n = 2).

DISCUSSION

The current study indicates that combined proximal embolic protection and thrombus aspiration has no demonstrable effect

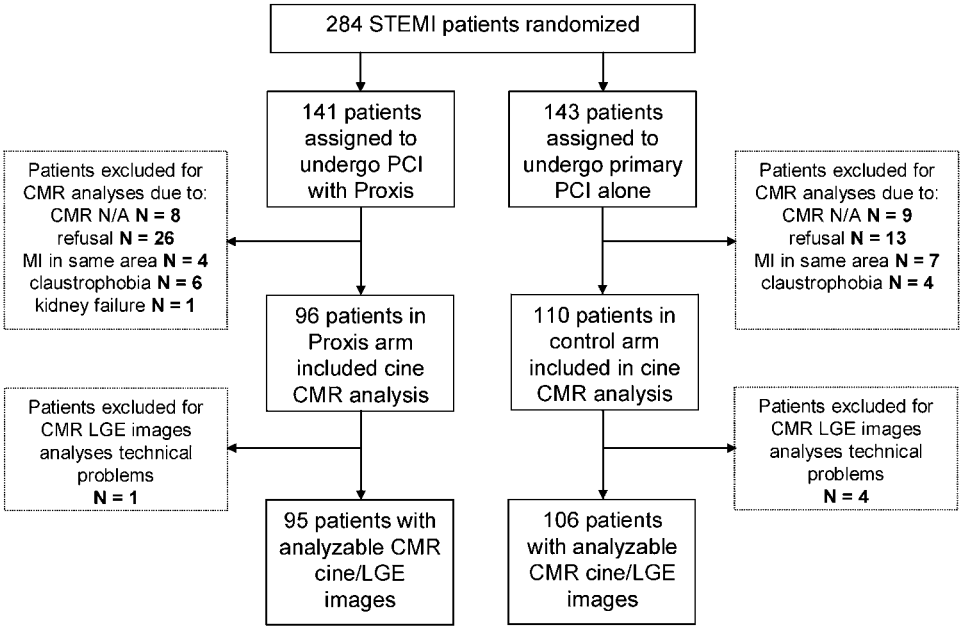

Figure 2 Flow chart of patients included in the ancillary cardiovascular magnetic resonance (CMR) study. LGE, late gadolinium enhancement; MI, myocardial infarction; N/A, not available; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.

Table 1 Baseline and procedural characteristics and angiographic outcomes of the patients

	PCI with Proxis (n = 96)	Primary PCI alone (n = 110)	p Value
Age, years (SD)	60 (10)	58 (11)	0.31
Male sex	83 (87%)	90 (82%)	0.37
BSA, m^2 (SD)	2.0 (0.2)	2.0 (0.2)	0.52
History			
Diabetes mellitus	10 (10%)	5 (5%)	0.11
Hypertension	25 (26%)	21 (19%)	0.23
Hypercholesterolaemia	14 (14%)	12 (11%)	0.43
Myocardial infarction	4 (4%)	5 (5%)	0.89
PCI	4 (4%)	4 (4%)	0.84
Cerebrovascular disease	3 (3%)	3 (3%)	0.87
Cardiovascular disease in family	34 (35%)	45 (41%)	0.42
Smoking	18 (19%)	12 (11%)	0.11
Current smoking	51 (53%)	76 (69%)	0.02
No of diseased vessels			0.52
1	64 (67%)	73 (66%)	
2	27 (28%)	27 (25%)	
3	5 (5%)	10 (9%)	
Infarct-related vessel			0.84
Left anterior descending artery	29 (30%)	32 (29%)	
Left circumflex artery	11 (11%)	12 (11%)	
Right coronary artery	56 (58%)	66 (60%)	
Baseline TIMI-graded flow			0.19
0	89 (93%)	102 (93%)	
1	7 (7%)	5 (5%)	
2	0 (0%)	3 (3%)	
Visible thrombus	72 (75%)	73 (66%)	0.18
Proxis placed	90 (94%)	…	
Glycoprotein IIb/IIIa receptor antagonists	42 (44%)	38 (35%)	0.18
Symptom onset to balloon, minutes	162 (131–232)	155 (126–211)	0.22
TIMI-graded flow			0.52
0–1	0 (0%)	1 (1%)	
2	7 (7%)	9 (8%)	
3	89 (93%)	100 (91%)	
Myocardial blush grade			0.26
0–1	4 (4%)	5 (5%)	
2	16 (17%)	9 (8%)	
3	75 (79%)	96 (87%)	
Angiographic signs of distal embolisation	11 (12%)	17 (16%)	0.42
Infarct size by peak CK-MB, μg/l	208 (136–394)	235 (149–389)	0.46

Data are expressed as mean (SD), median (interquartile range), or number of patients (%). Data for myocardial blush grade were available for 95 in the percutaneous coronary intervention (PCI) with Proxis group and 110 in the primary PCI alone group, for infarct size by peak creatine kinase-myocardial band (CK-MB), 66 and 65, respectively, and for angiographic signs of distal embolisation, 95 and 109. BSA, body surface area; TIMI, thrombolysis in myocardial infarction.

on either final infarct size or left ventricular function at follow-up. This finding was in spite of significantly more robust ST-segment resolution at the last contrast injection in the Proxis arm.

Several explanations may be proposed as to why combined embolic protection and thrombus aspiration succeeded to enhance myocardial reperfusion success, as observed by more early ST-segment resolution and a reduction in ECG injury

Table 2 CMR outcomes

	PCI with Proxis (SD)	Primary PCI alone (SD)	p Value
Functional	(n = 96)	(n = 110)	
End-diastolic LV mass, g/m^2	47 (10)	47 (11)	0.84
LV end-diastolic volume index, ml/m^2	92 (25)	93 (27)	0.84
LV end-systolic volume index, ml/m^2	47 (23)	49 (26)	0.75
LV ejection fraction, %	50 (11)	50 (12)	0.46
Systolic wall thickening in infarct area, %	44 (26)	45 (28)	0.93
Late gadolinium enhancement	(n = 95)	(n = 106)	
Infarct size, g/m^2	6.1 (5.3)	6.3 (6.1)	0.78
Extent of transmural segments, % of segments	8.3 (10.8)	8.3 (12)	0.60

Data are expressed as mean (SD). CMR, cardiovascular magnetic resonance; LV, left ventricular; PCI, percutaneous coronary intervention.

Table 3 Clinical endpoints at 6 months

	PCI with Proxis (n = 141)	Primary PCI alone (n = 143)	p Value
Death	2	4	
Spontaneous myocardial infarction	2	2	
Procedural myocardial infarction*	1	1	
Percutaneous target lesion revascularisation	5	5	
Percutaneous target vessel revascularisation	6	7	
Surgical target vessel revascularisation	1	3	
Acute stent closure	2	2	
Stroke	0	2	
Overall major adverse cardiac or cerebral events	11	15	0.43
Percutaneous non-target vessel revascularisation	10	12	
Surgical non-target vessel revascularisation	0	0	

Data are expressed as the number of patients. *Myocardial infarction related to additional percutaneous coronary intervention (PCI).

current over time, but failed to reduce final infarct size or improve left ventricular function.

First, complete ST-segment resolution immediately at the end of PCI occurred significantly more frequently in the Proxis-treated patients, but this effect evanesced over time. Mechanistically, the very early time frame of measurable benefit is conceptually consistent with the prevention of distal embolisation.[3] This transient effect could have translated into a reduction in final infarct size or better preservation of left ventricular function. However, we could not detect any clinically relevant differences between the two study groups in the indices of final infarct size or left ventricular function. Notably, despite the fact that the Thrombus Aspiration during Percutaneous Coronary Intervention in Acute Myocardial Infarction Study (TAPAS) demonstrated a significant reduction in one-year mortality,[2] previous trials of thrombectomy devices have shown conflicting effects on infarct size and left ventricular function.[1 9 10]

Second, the mechanism underlying reduced myocardial perfusion and suboptimal myocardial salvage after primary PCI in STEMI patients is probably multifactorial.[11 12] Even though the use of combined proximal embolic protection and thrombus aspiration could prevent embolisation during every step of the procedure, the dynamic nature of thrombus formation and endogenous lysis may cause distal embolisation and microvascular obstruction to be initiated before PCI. Moreover, such intervention may be not sufficient to achieve meaningful myocardial salvage in a disease state characterised by systemic and local mediators of inflammation and endothelial dysfunction, capillary leakage with interstitial oedema and reperfusion injury. Notably, the effectiveness of the Proxis system in PCI of saphenous vein grafts, as observed in the Proximal Protection During Saphenous Vein Graft Intervention (PROXIMAL) trial, is indisputable.[13] The prevention of distal embolisation, a phenomenon frequently observed and consistently associated with periprocedural myocardial infarction and worse clinical outcome in saphenous vein graft procedures, was shown to be of significant benefit on clinical endpoints.[14] However, differences in emboli composition and altered physiology in the myocardium downstream of the embolisation as a result of prolonged ischaemia may significantly alter the transferability of this observation.

Third, it is possible that the potential benefits of the Proxis system are attenuated by the potentially harmful extension of complete occlusion of the infarct-related artery and subsequent prolonged ischaemia. The sequential and repetitive inflations of the sealing balloon of the Proxis system could have contributed to prolonged ischaemia and peak injury current during or after primary PCI, which has been associated with a larger infarct size.[15] Conversely, the above-mentioned mechanism is known as "ischaemic post-conditioning", indicating the prevention of lethal reperfusion injury by inducing transient episodes of ischaemia at the time of myocardial reperfusion.[16] Whether this mechanism is effective in humans is the subject of ongoing clinical trials.

Fourth, mainly because of the necessity for a "landing zone" for the Proxis system, patients with a myocardial infarction related to an ostial coronary artery occlusion were not included in the PREPARE trial. This resulted in more myocardial infarctions related to a right coronary artery (RCA) (60%) compared with a "normal" STEMI population and led to the exclusion of very proximal infarct-related left anterior descending artery (LAD) and left circumflex artery (LCx) lesions. The RCA typically perfuses a much smaller amount of left ventricle myocardium, and as such is associated with much smaller final infarct size. Also, patients with a non-proximal LAD or LCx-related lesion have a much smaller left ventricle myocardium at risk. This could have affected the results in two ways: because of the small amount of myocardium at risk, differences are harder to ascertain even on CMR and would necessitate a larger sample size to verify this effect or that the intervention had no or a negligible effect on RCA and non-proximal LAD or LCx-related myocardial infarctions. The preponderance of RCA lesions and non-proximal lesions of the LAD and LCx with subsequent smaller myocardial infarctions may thus have diluted the effect size that might have been seen in proximal LAD and LCx lesions with larger amounts of myocardium at risk.

Limitations

We used final infarct size measured by gadolinium-enhanced CMR as the primary endpoint to ascertain the benefit of combined proximal embolic protection and thrombus aspiration. Final infarct size has been consistently associated with clinical outcome and is assessed with high sensitivity by gadolinium-enhanced CMR, but ultimately remains a surrogate for clinical endpoints.

CONCLUSIONS

Combined proximal embolic protection and thrombus aspiration in patients with STEMI treated with primary PCI did not result in a reduction in final infarct size or better preservation of the left ventricular function at follow-up.

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Competing interests None.

Ethics approval The study protocol was approved by the institutional review board of the Academic Medical Center, University of Amsterdam.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Sardella G,** Mancone M, Bucciarelli-Ducci C, *et al*. Thrombus aspiration during primary percutaneous coronary intervention improves myocardial reperfusion and reduces infarct size: the EXPIRA (thrombectomy with export catheter in infarct-related artery during primary percutaneous coronary intervention) prospective, randomized trial. *J Am Coll Cardiol* 2009;**53**:309–15.

2. **Vlaar PJ,** Svilaas T, Van der Horst I, *et al*. Cardiac death and reinfarction after 1 year in the Thrombus Aspiration during Percutaneous coronary intervention in Acute myocardial infarction Study (TAPAS): a 1-year follow-up study. *Lancet* 2008;**371**:1915—20.
3. **Haeck JD,** Koch KT, Bilodeau L, *et al*. Randomized comparison of primary percutaneous coronary intervention with combined proximal embolic protection and thrombus aspiration and primary percutaneous coronary intervention alone in ST-segment elevation myocardial infarction [abstract]. *J Am Coll Cardiol Cardiovasc Interv* 2009;**2**:934—43.
4. **Kim RJ,** Fieno DS, Parrish TB, *et al*. Relationship of MRI delayed contrast enhancement to irreversible injury, infarct age, and contractile function. *Circulation* 1999;**100**:1992—2002.
5. **Kim RJ,** Albert TS, Wible JH, *et al*. Performance of delayed-enhancement magnetic resonance imaging with gadoversetamide contrast for the detection and assessment of myocardial infarction: an international, multicenter, double-blinded, randomized trial. *Circulation* 2008;**117**:629—37.
6. **Koch KT,** Haeck JD, van der Schaaf RJ, *et al*. Proximal embolic protection with aspiration in percutaneous corononary intervention using the proxistrade mark device. *Rev Cardiovasc Med* 2007;**8**:160—6.
7. **Ripa RS,** Jorgensen E, Wang Y, *et al*. Stem cell mobilization induced by subcutaneous granulocyte-colony stimulating factor to improve cardiac regeneration after acute ST-elevation myocardial infarction: result of the double-blind, randomized, placebo-controlled stem cells in myocardial infarction (STEMMI) trial. *Circulation* 2006;**113**:1983—92.
8. **Hirsch A,** Nijveldt R, Haeck JD, *et al*. Relation between the assessment of microvascular injury by cardiovascular magnetic resonance and coronary Doppler flow velocity measurements in patients with acute anterior wall myocardial infarction. *J Am Coll Cardiol* 2008;**51**:2230—8.
9. **Kaltoft A,** Bottcher M, Nielsen SS, *et al*. Routine thrombectomy in percutaneous coronary intervention for acute ST-segment-elevation myocardial infarction: a randomized, controlled trial. *Circulation* 2006;**114**:40—7.
10. **Stone GW,** Webb J, Cox DA, *et al*. Distal microcirculatory protection during percutaneous coronary intervention in acute ST-segment elevation myocardial infarction: a randomized controlled trial. *JAMA* 2005;**293**: 1063—72.
11. **Ito H.** No-reflow phenomenon and prognosis in patients with acute myocardial infarction. *Nat Clin Pract Cardiovasc Med* 2006;**3**:499—506.
12. **Lerman A,** Holmes DR, Herrmann J, *et al*. Microcirculatory dysfunction in ST-elevation myocardial infarction: cause, consequence, or both? *Eur Heart J* 2007;**28**:788—97.
13. **Mauri L,** Cox D, Hermiller J, *et al*. The PROXIMAL trial: proximal protection during saphenous vein graft intervention using the Proxis Embolic Protection System: a randomized, prospective, multicenter clinical trial. *J Am Coll Cardiol* 2007;**50**:1442—9.
14. **Coolong A,** Baim DS, Kuntz RE, *et al*. Saphenous vein graft stenting and major adverse cardiac events: a predictive model derived from a pooled analysis of 3958 patients. *Circulation* 2008;**117**:790—7.
15. **Terkelsen CJ,** Kaltoft AK, Norgaard BL, *et al*. ST changes before and during primary percutaneous coronary intervention predict final infarct size in patients with ST elevation myocardial infarction. *J Electrocardiol* 2009;**42**:64—72.
16. **Thibault H,** Piot C, Staat P, *et al*. Long-term benefit of postconditioning. *Circulation* 2008;**117**:1037—44.

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