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REVIEW

## Coronary microcirculation in acute myocardial ischaemia: From non-invasive to invasive absolute flow assessment

*Microcirculation coronaire après un syndrome coronarien aigu : de l'évaluation non invasive à la mesure invasive du flux absolue coronaire en pratique clinique*

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### KEYWORDS

Acute coronary syndrome;  
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**Summary** Although substantial progress has been made in recent decades in reducing mortality and performing optimal revascularization in patients with myocardial infarction, ischaemic heart disease, including acute coronary syndrome, remains the leading cause of mortality worldwide. One of the remaining challenges is to better detect, prevent and treat extended myocardial damage despite angiographically optimal revascularization. Several indices are available in clinical practice to evaluate myocardial damage, infarct size and potential myocardial recovery. These indices are divided into two categories: non-invasive, generally performed after revascularization; and invasive, performed during the revascularization procedure. They

**Abbreviations:** ACS, acute coronary syndrome; CFR, coronary flow reserve; CMR, cardiac magnetic resonance; FFR, fractional flow reserve; IMR, index of microvascular resistance; MACE, major adverse cardiac events; MCE, myocardial contrast echocardiography; MVO, microvascular obstruction; NSTEMI, non-ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; PET, positron emission tomography; STEMI, ST-segment elevation myocardial infarction; STR, ST-segment elevation resolution; TIMI, Thrombolysis In Myocardial Infarction.

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allow the clinician to detect patients at risk and may help us to tailor the medical therapy and discharge strategy according to myocardial damage. Because of the number of indices, it is difficult to properly evaluate new therapeutics or to adopt one index that will provide sufficient data to better evaluate and understand the part of the coronary vasculature that is not seen – the microcirculation or so-called “black box”. The aim of this review is to describe the non-invasive and invasive indices used to describe the microcirculation and their ability to predict clinical impact, and current dedicated therapeutics that may help to reduce microvascular damage and improve clinical outcomes.

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## MOTS CLÉS

Syndrome coronarien aigu ;  
Dommage myocardique ;  
Microcirculation coronaire

**Résumé** Malgré les progrès substantiels en cardiologie qui ont permis de réduire la mortalité cardiovasculaire ces dernières décennies, la cardiopathie ischémique incluant le syndrome coronaire aigu demeure la cause la plus importante de mortalité dans le monde. Un des défis actuels est de mieux prévenir, de détecter et de traiter les dommages myocardiques malgré une revascularisation angiographiquement optimale. Plusieurs indices sont actuellement disponibles en pratique clinique afin de détecter l'évolution vers une nécrose myocardique étendue. Ces indices peuvent être non invasifs, généralement réalisés après la procédure de revascularisation, ou invasifs, réalisés pendant la même procédure, après revascularisation. Ces indices permettent aux cliniciens de détecter les patients à risque afin d'adapter précocement la stratégie médicale en terme de médication et de retour au domicile. Devant le nombre important d'indices, il est difficile d'évaluer les traitements et les stratégies thérapeutiques qui permettraient de réduire ces dommages myocardiques et microcirculatoires post revascularisation d'un syndrome coronaire aigu. L'objectif de cette revue est de décrire les principes de ces indices non invasifs et invasifs permettant d'évaluer l'atteinte microcirculatoire et myocardique post infarctus du myocarde, leurs implications cliniques ainsi que les thérapeutiques actuellement employées et en cours d'évaluation.

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## Background

Despite advances in recent decades in the treatment of acute coronary syndromes (ACS) [1], most progress has been in the field of epicardial coronary artery revascularization. The coronary tree can be divided into two main compartments, which regulate blood flow into the myocardium. The macrocirculation, which is composed of epicardial vessels, mainly assures conductance, whereas the microcirculation, composed of small vessels, mainly assures resistance (Fig. 1). While the macrocirculation is seen with coronary angiography, it represents only 5–10% of the overall coronary vasculature. The most important part of the coronary tree – the microcirculation – is not seen and is therefore poorly assessed during and after an ACS [2]. Even in the early phase of an ACS, with state-of-the-art therapeutics, although interventional cardiologists can treat acute epicardial artery occlusion effectively, myocardial damage can remain high, as a result of microcirculation impairment [3].

In this review, we describe the non-invasive and invasive techniques for evaluating the coronary microcirculation, the prognosis of microcirculation impairment after an ACS, the therapeutic targets and perspectives for the treatment of the microcirculation, which may represent the next research challenge in improving prognosis after an ACS.

## Non-invasive evaluation of the microcirculation

### Electrocardiography

In the thrombolytic era, several studies demonstrated that in patients with ST-segment elevation myocardial infarction (STEMI), rapid ST-segment elevation resolution (STR) after fibrinolysis strongly suggested effective reperfusion of the occluded infarct-related artery [4]. In contrast, persistent ST-segment elevation (Fig. 1A) or incomplete STR after treatment was frequently associated with fibrinolysis failure to save the myocardial area at risk of necrosis, suggesting a failure to restore epicardial coronary blood flow. Nevertheless, when primary percutaneous coronary interventions (PCI) were commonly performed to treat STEMI, it became clear that a lack of rapid STR did not necessarily indicate failure to recanalize the artery, but rather the inability to restore myocardial perfusion caused by microvascular obstruction, which has also been correlated with worse clinical outcome [5].

Several electrocardiogram variables have been investigated in the diagnosis of microvascular obstruction. These variables have been evaluated as markers of infarct size, impaired myocardial salvage, reperfusion injury and

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