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EDITORIAL COMMENT

Myocardial Edema in Acute Ischemic Injury*

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Our aim, as well as our mission, is to save the vulnerable patient. We can subdivide the problem into "vulnerable plaque," "vulnerable blood," and "vulnerable myocardium" (1,2). That still effective concept of vulnerable myocardium" also included the differentiation of myocardial tissue in nonischemic and ischemic heart disease including acute injury. The overall idea was to identify the vulnerable patient before life-threatening arrhythmias, the development of acute events, or heart failure occurs or worsens. Therefore, a well-defined strategy is needed. Although no one is expected to find the Holy Grail in the near future, a strategy is needed that includes clinical aspects and integrated biomarkers. Imaging offers the chance to get insight into an injury that meets the overall expectation of a biomarker (3) and offers the chance to enhance the ability of a clinician to manage the patient optimally. That would mean in the case of acute injury having an effective, robust technique of added value to visualize the tissue damage before irreversible myocardial changes develop.

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Cardiac magnetic resonance (CMR) is able to image noninvasively and without radiation to the "vulnerable myocardium," including differentiating myocardial injury in ischemic and nonischemic heart disease by using different techniques with and without the use of contrast-media enhanced techniques. The application of T2-weighted imaging has opened the door to visualizing myocardial edema. Friedrich (4) discussed edema as a generic component of the tissue response to acute injury. Therefore, the technique could become an important diagnostic tool for assessing the acuity of tissue damage in vivo and the potential use of water-sensitive CMR to visualize alterations in vivo. CMR has an important role in patients with acute myocardial infarction.

Late gadolinium enhancement (LGE) can detect infarct scarring in coronary artery disease (5). This method can identify even small subendocardial lesions that are not detectable by single-photon emission computed tomography (6). CMR findings were shown to have prognostic value (7), and CMR can also distinguish between acute and chronic changes after myocardial infarction (8). Furthermore, the area at risk was identified by the bright area on T2-weighted imaging in canine models (9) and verified in patients (10). The myocardial salvage index, which is calculated as the area at risk minus the infarct size divided by the area at risk, predicts the outcome in acute myocardial infarction (11). Finally, T2-weighted imaging results augmented other prognostic information (12).

The application of combined imaging protocols, including contrast-enhanced sequences, offers the unique possibility of differentiating reversible and irreversible injury not only in ischemic but also in inflammatory disease (13). That perception led to a consensus paper proposing a combined CMR protocol in inflammatory disease (14).

A recent review article summarized the capabilities of CMR in acute coronary syndrome (15). There is preliminary evidence from a canine model that T2-weighted imaging of edema allows the detection of acute ischemic myocyte injury before LGE is visible (16). The circumstances are such that LGE is already detectable in the first hour after the onset of ischemia, which could be the case even in patients (17). Thus, its use is all the more attractive. T2-weighted imaging is

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helpful in terms of decision making in patients with acute chest pain who present to the emergency department (18).

A comprehensive view on different stages of myocardial injury is needed without any doubt, but the imaging-technique itself is sometimes difficult due to technical limitations. Different T2-weighted techniques are used to provide imaging of edema. In 1996, a "black blood" T2-weighted inversion recovery technique was introduced by Simonetti et al. (19), leading to widespread use. Fast spin echo sequences are often used, but commonly have several limitations including dependence on the patient's condition, as discussed elsewhere (20,21). Alternative sequences were introduced to offer robust approaches for the detection of acute myocardial infarction–related edema including T2-prepared steady-state free precession—(22) and T2 turbo spin echo steady-state free precession sequences (23). Nevertheless, in myocardial disorders with homogeneous edema, a quantitative approach would be superior compared with a qualitative one. Moreover, this approach could overcome coil-related inhomogeneities. Therefore, quantitative mapping techniques could offer an alternative to current techniques. In 2009, Giri et al. (24) introduced a quantitative T2 mapping approach. This approach has the potential to increase the accuracy of the detection of myocardial edema. In this issue of *iJACC*, the same group (25), led by Raman, has provided evidence that the concept is valid in a clinical setting. They evaluated quantitative T2 mapping in a 16-segment model and compared it with conventional T2-weighted imaging in 27 patients with acute myocardial infarction. The T2 of the infarct zone was significantly higher compared with the T2 of the remote myocardium in non–ST-segment elevation myocardial infarction and ST-segment elevation myocardial infarction. Verhaert et al. (25) showed that the T2 of remote myocardium was not different from that of volunteers. Furthermore, T2 maps yield more robust findings than conventional short tau inversion recovery (STIR). The STIR was uninterpretable in 7% (2 patients), and edema was not detectable in others, mainly those with NSTEMI. Therefore, the investigators concluded that quantitative T2 mapping reliably identifies myocardial edema without the limitations encountered by T2 STIR imaging. Furthermore, the method may be clinically more robust compared with other methods in terms of revealing acute ischemic injury. Although these results are very promising, we are aware that the number of patients was small and confirmatory data will be necessary.

CMR can detect myocardial injury, even in the presence of preserved ejection fraction and absent fibrotic transformation of the myocardium. Particularly in inflammatory disease, the quantification of a diffuse myocardial edema is a challenge that could be assisted by mapping techniques. A quantitative approach could give us insight into underlying mechanisms, evolving myocardial injury, and early therapeutic intervention. In this regard, Verhaert et al. (25) have moved us 1 step further.

Although the clinical needs are mainly defined, further technical development such as 3-dimensional approaches with a high spatial resolution are warranted but must be proven to meet the required diagnostic accuracy.

Having techniques such as this, CMR should be a part of a diagnostic workup and a part of a multimodality disease-dedicated concept by offering its unique features.

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