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EDITORIAL COMMENT

CMR Mapping Techniques for Myocardium at Risk

Next Step Into a Bright Future?*

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"The future depends on what you do today."
—Mahatma Gandhi (1)

In the setting of myocardial infarction (MI) rapid reperfusion of acutely ischemic, but yet only reversibly injured, myocardium has the potential for salvaging viable myocytes. The assessment of myocardial salvage is clinically important because significant salvage is associated with improved short- and long-term survival after infarction (2,3). Moreover, noninvasive imaging methods that can delineate the area at risk (AAR) and salvageable myocardium are crucial in assessing the efficacy of therapeutic approaches, including reperfusion.

See page 596

In recent years, cardiac magnetic resonance (CMR) has emerged as the clinically most feasible and accurate noninvasive tool to quantify the AAR and myocardial salvage (4,5). Numerous studies have clearly demonstrated that myocardial salvage assessment by CMR not only is reproducible (6), but also sensitively identifies and accurately quantifies myocardial salvage in excellent agreement with histopathology (7,8), single-photon emission computed tomography (9), and angiographic scores of myocardial salvage (10).

Most of the clinical experience in visualizing the myocardium at risk has been reported for short-TI triple-inversion recovery prepared fast spin echo (STIR) sequences (2,4–6,9,10). Hyperintense regions are thought to mark edematous myocardium, which reflects the entire AAR (including both reversible and irreversible injury). The salvaged AAR remains noninfarcted as a result of successful reperfusion.

The STIR technique usually provides images with diagnostic quality, allowing a clinically useful interpretation in most patients. T2-weighted images, however, may be hampered by poor image quality and artifacts affecting data analysis and interpretation (4,11). Although T2-weighted imaging technology has improved substantially in recent years, some still believe that T2-weighted imaging for delineating the AAR is a "risky business" (11). However, as cogently reviewed by Friedrich et al. (12) in a recent *iForum* in this journal, in light of our clinical experience and many other CMR centers worldwide, the T2-weighted technique offers tremendous potential for a better understanding of myocardial injury, post-revascularization pathophysiology, and quantifying the success of acute reperfusion.

Despite this enthusiasm, there is general agreement in the CMR community that CMR protocols for edema detection still require further optimization. Fortunately, better T2-weighted CMR methods are in development or being evaluated (13,14). The potentially most promising stride for CMR imaging of the myocardium at risk is the direct measurement of T2 relaxation times by T2 mapping (15). This method has the potential to improve objectivity of T2-weighted imaging and might be less dependent on confounders affecting signal intensity and image quality. T1 mapping might also be useful for assessing myocardium at risk, but, as with T2 mapping, published data are scarce.

In this issue of *iJACC*, Ugander et al. (16) take an important step toward improving the validation and

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utility of quantitative T1 and T2 mapping for assessment of myocardial edema/AAR. CMR was performed in a canine occlusion-reperfusion model using clinically available T1 mapping (Modified Look-Locker Inversion-recovery [MOLLI]) and T2 mapping (T2-prepared steady-state free precession) sequences, and the results were compared with pathological assessment of the AAR with microspheres as an independent reference standard. An excellent agreement and correlation between both mapping methods and microsphere results was observed.

This thoughtful work is very much appreciated and needed as it represents: 1) the first experimental validation of T1 and T2 mapping techniques with an appropriate pathology reference of the AAR; 2) an important expansion of previous work by including whole-heart volumetric measurements of the AAR by CMR and microspheres; 3) an additional demonstration and confirmation that T1 and T2 increases detect changes in the myocardium at risk; and 4) the first study to show that in vivo non–contrast T1 mapping by CMR can also accurately quantify the AAR.

Indeed, a very interesting finding of the work by Ugander et al. (16) is that not only myocardial T2, which is known to be sensitive to changes in tissue water content, but also myocardial T1 changes after acute reperfused MI in ways that are consistent with myocardial edema. This finding is in line with earlier reports that also demonstrated a relation of prolonged T1 relaxation times and increased myocardial water content in ischemically injured myocardium (17,18). Pre-contrast T1 mapping therefore represents a new method for imaging the AAR.

From a pathophysiological point of view, the changes in T1 and T2 rely on similar pathophysiological mechanisms associated with ischemia-induced edema formation in the myocardium, with similar strengths and limitations. However, T1- and T2-weighted sequences are different from an MR physics point of view with consequently different artifacts and susceptibility to other markers of reperfusion injury (e.g., microvascular obstruction, intramyocardial hemorrhage) (19,20). Ugander et al. (16) carefully point out that both mapping techniques provide similar information with respect to AAR, and could even be used interchangeably for this purpose. Thus, future studies should address which of these mapping techniques is preferable for quantification of the myocardium at risk, considering image quality, artifacts, reproducibility, and acquisition time. Furthermore, additional studies are required to fully understand what role T1 mapping may play in visualizing myocardial edema, AAR, and myocardial salvage.

What are the clinical consequences of this pivotal work? Should we abandon STIR sequences from our scanners in favor of quantitative T2 or T1 mapping? This is probably too early as we need more human data for T2 mapping and even more for T1 mapping, including clinical settings. These data are necessary for the quantification of myocardium at risk in acute MI, but also for other cardiac diseases that are known to cause global or regional edema (e.g., acute coronary syndromes, myocarditis, stress cardiomyopathy) (4,21). However, the new mapping sequences have the potential for a more reliable detection of myocardial edema by minimizing artifacts associated with conventional T2-weighted imaging and preventing subjective interpretation. Furthermore, T1 and T2 differences between edematous and noninfarcted myocardium may be more easily detected with hard cutoff values.

The take-home message of the study by Ugander et al. (16) is that, although accurate CMR approaches for assessing the myocardium at risk are already available, even more reliable, robust, and now validated techniques are under way and may soon be available. This further increases the lead of CMR over other imaging modalities in characterizing tissue pathology for diagnosis and therapy. Surely, these mapping techniques have to be tested in various clinical settings and larger cohorts before broad clinical utilization, but studies like these pave the way for a bright future of CMR assessment of the myocardium at risk and myocardial salvage.

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Key Words: cardiac magnetic resonance ■ myocardial infarction ■ myocardium at risk ■ T1 mapping ■ T2 mapping.