Myocardial Tissue Characterization - Clinical Needs: What Do We Want to See?

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Introduction

In the last decades, mortality in cardiology decreased particularly in patients with ischemic heart disease due to both, improvements in diagnostics but also and particularly due to novel treatment strategies. Nevertheless, as the prevalence of cardiac diseases increases within the aging population, management of cardiac diseases remains a challenge.

Open questions

The main prognostic factor for outcome in coronary artery disease (CAD) is ischemia burden. Therefore, the most important tissue characteristics to manage CAD patients is ischemia detection and quantification. Here, the question remains how much ischemia is required to affect outcome, or in other words, which treatment (conservative drug treatment, revascularization by percutaneous interventions or by surgery, antiarrhythmic treatment) has to be chosen for which level of ischemia burden. Thus, the role of ischemia quantification in terms of grading vs absolute quantification has to be addressed.

As a short-term manifestation of ischemia tissue edema can develop. In the setting of acute coronary syndromes (ACS) including ST-elevation (STEMI) and non-ST-elevation myocardial infarction (NSTEMI), tissue edema develops in the area-at-risk. Therefore, edema quantification offers a big potential to measure the amount of myocardium at risk, and consequently, to monitor treatment effects in ACS (i.e. STEMI and NSTEMI). Hence, T2-weighted imaging will most likely play an important role in treatment monitoring in ACS.

Long-standing ischemia will progress to necrosis. Late gadolinium enhancement (LGE) is a well established technique to quantify irreversible tissue damage. Evidence accumulates, that microvascular obstruction and/or hemorrhage are also strong predictors of adverse remodeling and poor outcome. To better understand the contribution of these characteristics to outcome prediction, quantification of distribution volume would be desirable, most likely achievable by novel T1 mapping techniques.

Arrhythmias are the major contributor to sudden cardiac death (SCD). Within this category of ventricular arrhythmias, re-entry is a prevalent mechanism. Therefore, tissue characterization will be important to detect patients with potentially dangerous re-entry conditions. Most likely scar tissue and its border zone are an important substrate for re-entry mechanisms. A major goal in SCD prevention could be the characterization and quantification of the scar border zone in terms of content of scar, ischemia, and edema.

Both, systolic as well as diastolic dysfunction are associated with poor outcome. However, diastolic dysfunction is still poorly understood and methods to detect and quantify diastolic dysfunction are not yet well established. Thus, methods to reproducibly quantify diastolic dysfunction are needed.

A central question in the setting of acute ischemia (with systolic dysfunction) as well as in the setting of diastolic dysfunction is asking for its etiology. Severe metabolic changes occur during ischemia and ischemia reperfusion, and they might be also implicated in diastolic dysfunction. Therefore, it would
be of paramount importance to characterize tissue metabolism. Novel hyperpolarized 13C-carbon MR imaging will most likely allow us to characterizing the metabolic status of the tissue and thus, will most likely improve our understanding of fundamental tissue properties. Ultimately, this understanding will stimulate the development of new treatment strategies and these 13C-carbon techniques will be used to monitor treatment responses.

Currently, tissue characterization is based on measurements of physical properties. MR can probe these properties by measuring T1 and T2 characteristics, e.g. by changing them through the administration of T1-enhancing contrast media (gadolinium-chelates) to assess tissue perfusion or cell integrity or to estimate water content, respectively. A much more detailed understanding of tissue functioning will be achieved, if we are able to detect specific cell types in the tissue. This approach will be much more specific than looking at physical tissue characteristics. Fluorine-MR may open this spectrum of cell-specific tissue characterization, as this technique allows to specifically detecting and tracking well defined cell populations.