Evolution and Revolution in CMR Imaging

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Revolution is a fundamental change that takes place in a relatively short period of time.

Evolution is the change in characteristics over successive generations. Evolutionary processes give rise to diversity at every level of organization.

In this issue of iJACC, we publish a review from Salerno and Kramer on novel quantitative approaches for CMR. The report highlights the drastic changes the field is experiencing and will continue to experience in the ensuing years. Tools, which have been lingering around for several years are now ready for clinical use, some of them waiting for application and some of them with immediate utility. To understand the power of this change it is important to understand the dynamics of change in the field of CMR, which are different than in many other fields of imaging and medicine.

CMR is a continuously evolving technique. While with some imaging techniques the major changes occur from changing the hardware (e.g. upgrade form 4- to 16- to 64-slice or beyond in CT, or from M-mode to 2D and 3D in echocardiography), CMR evolves in small steps with many parameters involved in data acquisition, reconstruction, and post-processing. Even the change from 1.5- to 3-T did not lead to a major change in practice. While this leads to a wealth of new opportunities and continuous expansion of possibilities and indications, it also leads to a continuous technical drift with the danger of lack of standardization and focus on technical issues rather than on medical questions. Frequently this results in questions from funders (“Is this a drift of a step-change?”), reviewers (“Why did you not use the recently technique published from our group?”), and users (“Is it ready for clinical application?”).

CMR is a fully established technique in clinical cardiology today. The main success for CMR today is based on a “revolution” (such as the introduction of late gadolinium enhancement imaging to detect scar and fibrosis in 1999) as well as the “evolution” (such as perfusion techniques evolving into robust clinical tools). Both developments are independent and offer strong risk predictors providing excellent outcome data, allow robust diagnostic accuracy, as well as incremental support to patient management.

We are now observing another “revolution” of CMR, the change from visualization to quantification. Some of this has immediate clinical consequences. The first successful example of quantitative tissue characterization with CMR was the development, standardization, clinical validation, and wide implementation of T2* measurements, leading to completely new pathways of managing patients (such as hemochromatosis by guiding their management on cardiac iron overload rather than liver iron of blood values). The success story of T2* mapping shows several components which may be important for the current developments in perfusion quantification as well as T1 and T2 mapping. First, T2* measurements had an immediate clinical application. Second, the findings could be used to guide patient management, as there was an efficient therapy. The impact of a measurement tool with no application or an application with no efficient therapy would obviously have been much smaller. Third, the success of T2* measurements was based on the provision of normal and abnormal values for a given imaging and post-processing pathway. It was (and still is) more important that T2* measurements allow to make therapeutic decisions, than whether it reflects the true T2* or the true iron content. The importance is that we know which value is normal for a given scanner, sequence, and post-processing tool, and what abnormal values mean.

Do we see similar conditions for the upcoming tools? Perfusion quantification has several immediate clinical applications ranging from the decision on
revascularization based on presence and extent rather than the pure presence of ischemia, to the effective assessment of microvascular disease and triple vessel disease. In addition, there are other applications, such as follow-up, assessment of the effectiveness of (drug) therapy, and risk stratification. It is not entirely understood whether there is a truly effective therapy, and which patients would benefit from revascularization. While there is good data that patients with no ischemia should not be revascularized, there is much less evidence on the contrary. Currently recruiting trials will clarify whether patients with stable angina can be guided noninvasively by perfusion imaging (MR-INFORM) and whether revascularization of patients with moderate ischemia would benefit from revascularization (https://www.ischemiatrial.org). Absolute quantification also suffers from the evolutionary processes with multiple sequences and post-processing algorithms. One way to overcome these issues is by employing parameters that are based on an internal standard, such as myocardial perfusion reserve or transmural gradients.

T1 mapping also has some immediate clinical applications, such as detection and grading of amyloid disease and detection and risk assessment of various cardiomyopathies as well as quantification of myocardial involvement in valvular disease. However, since T1 mapping provides novel information, which is not yet available in the current literature, significant work will be required to define its clinical application. It will be important to focus on providing the clinical evidence, rather than focusing on technical development. This evidence will then also guide us toward effective therapy, such as device implantation, valve replacement, or the development and utilization of drugs, which reduce or reverse the development of myocardial fibrosis at an early stage.

T2 mapping is farthest away from immediate clinical use. The assessment of edema will help to understand the area at risk and diagnose acute inflammatory diseases, such as myocarditis. However, the former is mainly a research application and the latter has no specific therapy following the diagnosis. It is also important to understand the lack of a gold standard for reference, unlike the utility of PET or SPECT for the assessment of perfusion imaging. For T1- and T2-mapping novel sequences may be closer to T1 and T2 phantoms, thus measuring these physical parameters more accurately, the more important question, however, is how well they measure fibrosis, differentiate into reversible and irreversible fibrosis, measure water content, differentiate into interstitial or intracellular water, and guide us towards clinical decision making. The impact of a revolution, even in a small field, such as CMR may be considerable.

REFERENCES