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From Alpha to Omega: The Breadth in Cardiovascular Magnetic Resonance

Introduction

Does anyone else have a strong sense of déjà vu? Unfortunately, we will once again be unable to gather in person for the SCMR 2022 scientific sessions. However, we will gather virtually in the spirit of cardiovascular magnetic resonance (CMR) and listen to all the great minds in the fields of CMR (list is purely alphabetical) development, education, engineering, operation, research, and teaching. Ultimately, these magnetic forces will bond all of us for the benefit of our patients.

"Alpha to omega" plots a line from the first to the last letter of the Greek alphabet, and often symbolizes moving from the beginning to the end, or the comprehensiveness of something.

Efforts to image the cardiac affection and myocardial damage related to SARS-CoV-2 infection and the possible effects of vaccinations have been a focus of CMR research throughout the almost two years of the pandemic that has changed today's society in so many ways. However, the entire field of CMR and its broad applications have continued to grow and gain further attention in clinical use and guideline recommendations.

This issue of MAGNETOM Flash highlights some of the many nuances in CMR today, ranging from imaging strategies and technical tips & tricks, to the diagnostic and prognostic use of CMR in various diseases. It highlights the importance of a team approach and each other's understanding of planning, acquisition, and interpretation. Many people contribute to a successful CMR program, and recognition of everyone's expertise remains a highly important predictor of success. This is in no way different to applications of MR imaging in other parts of the body. Technologists' skills in scanning patients and acquiring data will undoubtedly help the diagnostic assessment by experts interpreting the available data and ultimately support clinical patient management and therapy decisions.

While the following might look like an arbitrary approach, it is meant to capture the bigger picture in CMR – from acquisition to diagnosis viewed from a clinical diagnostic perspective.

The never-ending story

The acquisition of image data undoubtedly represents the beginning (the alpha) of every patient's journey in CMR. Furthermore, the successful sampling of high-quality image data remains key for the diagnostic interpretation and ultimately impacts patient handling, final diagnosis, and therapeutic management.

Simplification of data acquisition and changes in CMR imaging strategies is not a story of the past, but rather one

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that continues to this day. Besides optimizing image quality and workflows, improving patient comfort and boosting overall efficiency in a busy healthcare environment also remain key for the continued success of CMR in the era of multi-modality approaches to disease assessment. This not only applies to the cardiac component of CMR, but also to the vast field of vascular imaging across the body.

Day optimizing throughput (Dot) engines have been supporting improved and more consistent slice planning as well as patient-adapted workflow strategies for many years. Without doubt, this has improved test-retest comparability in patients with serial CMR exams. Further improvement and integration of AI-based approaches will further reduce the complexity of CMR and increase efficiency. "Lean" imaging with reduced localization aspects compared to diagnostic acquisitions has become a main interest in CMR.

While this may work for most patients, challenges remain in a few, yet important situations. Not only do external factors such as implanted devices pose challenges, but size also matters in terms of whether one is imaging adult coronary arteries or performing CMR in the unborn[1].

For any MR imaging with implants, it is crucial to consider guidelines and recommendations with respect to MR safety, as well as applicable laws and device or MR imager labels. In any case, imaging in the proximity of metal structures remains challenging and while devices may be labeled as MR-conditional, image quality could still become non-diagnostic. In CMR, this specifically poses challenges for late gadolinium enhancement (LGE) imaging and depends on the type of cardiac implantable electronic device (CIED) and specifically also the location of the device generator. Vágó et al. nicely highlight the use of wideband (WB) LGE imaging alternatives in CIED patients where clinical CMR is thought to impact patient management (page 13). While standard LGE strategies specifically fail in the proximity of automated implantable cardioverter defibrillators (AICD) and cardiac resynchronization therapy (CRT) devices, the application of WB LGE provides scope for diagnostic LGE data sets if clinically appropriate. As such, not only patients with possible need of ablations may benefit but also patients who have received a CIED for various reasons and independent cardiac abnormalities may arise.

Speaking of abnormalities, ischemic heart disease requires not only LGE assessment but also the assessment of hemodynamic relevance of coronary artery stenosis. With the new AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR guidelines for the evaluation and diagnosis of chest pain, stress perfusion CMR is beginning to take center stage in such scenarios. Garot et al. expand the use of stress perfusion CMR to patients with CIED, on top of LGE scar imaging (page 8). This further supports the continuous improvement of CMR techniques by expanding into challenging territories.

Optimizing LGE imaging in non-CIED patients, and you think you know it all? In over 25 years of CMR experience, I have learned to appreciate every single hint and trick that might help improve overall image quality, speed up acquisition, reduce the need for gadolinium-based contrast agent (GBCA), or tease out subtle differential diagnoses. The ultimate source of many such tricks is still to be found in technologists/radiographers employing their tools regularly. This issue contains a "how-to" overview for implementing the LGE techniques that are currently available on the various platforms from Siemens Healthineers (page 48). Also don't miss the lively discussion of black/gray blood LGE techniques, an approach that specifically aims to improve delineation of subtle LGE in proximity of blood pool (e.g., in subendocardial areas). Such subtle LGE changes can often be the only sign of certain pathologies.

Imaging tiny structures or small patients[1] involves many challenges. Coronary MR angiography is a prime example, specifically given the prevalence of coronary artery disease (CAD) and its impact on healthcare systems

[1] *MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.*

and society. While CMR is undoubtedly the modality of choice for identifying myocardial viability and plays an ever-more important role in the functional testing of potentially hemodynamically relevant stenosis, the holy grail of CAD imaging remains anatomic imaging of the coronary arteries. This is where any potential therapeutic intervention will take place. The hunt for non-invasive coronary imaging began more than two decades ago with the advent of multi-detector row computed tomography (MDCT). In the best interests of our patients and healthcare systems, it remains crucial to consider the benefits and potential limitations of both modalities. Nevertheless, the continuous work by Hajhosseiny et al. (page 54) highlighted in this issue is impressive for its generally high image quality and good to very good diagnostic performance when compared to coronary CT angiography at a 50% stenosis cut-off level. Such work continues to provide confidence that coronary MR angiography[2] is a technique of the future rather than the past.

Similarly, imaging of the unborn heart presents challenges in the area of spatial and temporal resolution, among others. While fetal MR[1] has been performed for decades, CMR of the fetus, predominately for assessing congenital heart disease (CHD), has only recently attracted more attention – thanks to novel developments and technical improvements. In combination with fetal echocardiography, this aims to further improve pre-natal CHD diagnosis for therapy road-mapping. Hedström et al. (page 18) highlight developments in the field that led to today's advanced approaches. Furthermore, they expand on even more sophisticated non-invasive approaches for assessing physiological parameters such as blood flow and blood oxygenation.

Well, there is no way around this: Given the sheer number of patients in this pandemic and the rapidly growing evidence of myocardium affection by SARS-CoV-2, CMR absolutely had to be investigated in such settings. While the incidence of myocardial inflammation in COVID-19 patients has sparked endless discussions in the community, inoculation with mRNA vaccines and potential adverse cardiac events have also been a focus of debate among CMR professionals. In this issue, Francone's group highlights how quantitative mapping techniques can identify inflammatory changes related to COVID-19 myopericarditis (page 28). Undoubtedly, this confirms the contribution of mapping techniques to the diagnosis of myocarditis and myopericarditis using the modified Lake Louise Criteria.

With cardiomyopathies and their differentiation becoming an important task for CMR, easing and standardizing imaging protocols becomes a highly organizational aspect. One relevant issue is the need for repeated breath-holds during CMR, a task that can be so complex and demanding for the patient that image quality might substantially degrade. So why breath-holds? Pons-Lladó nicely demonstrates CMR imaging in cardiomyopathy with a free-breathing approach. It has taken a while, but CMR techniques seem to be finally there. With no need for patient recovery periods, such a strategy could cut standard cardiomyopathy CMR protocols to less than 30 minutes' scan time. This would dramatically improve patient comfort, operational workflow, and therefore scanner availability (page 22). Given potential paradigm challenges when applying free-breathing approaches to the employed mapping techniques, the accuracy and precision of quantitative results nevertheless may require further validation.

Athletes aiming to go faster, higher, stronger – in the manner of the Olympic motto Citius, Altius, Fortius – frequently need risk assessments or clearance before they can compete. Common protocols in professional and college-level sports have specifically been implemented to clear athletes after COVID-19 infection and thereby minimize risk. However, even without a threat as specific as COVID-19, athletes' hearts may pose challenges in light of their common adaptation to endurance and strength exposure. What many know simply as athlete's heart may show features that are also commonly seen in various cardiomyopathies. If such changes have been identified, CMR plays an increasingly important role in excluding or confirming potentially overlapping cardiomyopathies that could put athletes at risk when exercising. Especially among young athletes, sudden cardiac death (SCD) is of concern and has a number of possible underlying causes. Two articles in this issue cover this important topic and highlight various causes of SCD. They also elaborate on CMR approaches to identify risks and differentiate or confirm potential underlying cardiomyopathies (page 37, 43).

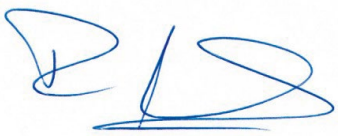
Clearly, after the broad coverage of cardiac topics above, there is an obligation to also highlight vascular imaging innovations. After all, CMR includes vascular imaging as well, doesn't it? To be fair, we may not all be too familiar with the small branches of the facial vasculature. If you want to get more insight into a smart non-contrast MR angiography technique to visualize facial arteries, look no further than this issue. The benefit of compressed sensing in acceleration of time-of-flight (TOF) MR angiography is known, as is the fact that elevated temperature typically results in vascular dilatation and flow increase. Combine the two and you end up with a technique called thermally enhanced 3D TOF MR angiography – with the increased blood flow achieved through heating (with infrared light). This substantially improves TOF MR angiography results,

[2]Work in progress. The application is currently under development and is not for sale in the U.S. and in other countries. Its future availability cannot be ensured.

as demonstrated by Mespreuve et al. (page 64). Could this potentially be used elsewhere? Watch out for future research endeavors.

Conclusion

We started at alpha, but is there an end for CMR, an omega? Well, that depends on everyone's personal definition. Over recent decades, MR techniques including CMR have hit bumps, but never walls. Technical developments, often based on fancy initial ideas, usually get rolling again and a new era in MR may dawn. Despite this continuous thriving, specifically in technical developments, we should not forget the highly important aspects that are required for the clinical translation of new and innovative CMR techniques. While many new techniques show promise in cohort studies and in predicting future outcomes, the daily diagnostic approach with a single patient being your cohort (n = 1) comes with additional needs and requires an especially high discriminatory power of CMR applications. Our patients are keen to know what their diagnosis is and are not necessarily interested in hearing about the likelihood of a disease and their statistical fate. Back to all the genius minds in CMR: I am more than certain that the translational "dilemma" of some applications will be solved for the benefit of our patients and the healthcare systems.



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