



Professor Eike Nagel, M.D., Ph.D. is a world-recognized opinion leader in cardiac imaging. For more than 25 years he has been using cardiovascular magnetic resonance imaging to diagnose problems of the heart or the vessels non-invasively. Professor Nagel has recently been appointed as Chair of Cardiovascular Imaging at the Goethe University Frankfurt, Germany, where he leads a new Cardiovascular Imaging Center equipped with magnetic resonance imaging and computed tomography. He focuses on the translation of new diagnostic tools into clinical routine particularly in the areas of coronary artery disease, cardiomyopathy and heart failure.

The Future of Cardiovascular Magnetic Resonance

This issue of MAGNETOM Flash highlights several developments and advances in the field of cardiovascular magnetic resonance imaging (CMR). They demonstrate the continuing development of this fascinating technique, which looks set to continue. A few general trends can be observed:

Quantification

CMR is becoming fully quantitative, as evidenced by the rapid development of mapping techniques quantifying T1 and T2 relaxation and allowing calculating extracellular volume. Several cases demonstrating its clinical value are shown in this issue. This development is a revolution in CMR imaging as we move away from black, white and grey values, visual assessment and contrast differences to fully quantifiable data approximating to physiology. While the development of these technologies is ongoing, we can already appreciate their value in the detection of early changes [1], assessment of underlying pathophysiology rather than its consequences [2] or quantification of alterations in absolute terms [3, 4]. Novel data also demonstrates that these quantifiable

measures are superior to classic markers such as volumes, ejection fraction and even late gadolinium enhancement in predicting cardiovascular events in patients with, for example, non-ischemic cardiomyopathies [5] or informing on the acuity of inflammation (myocarditis) [6]. Similar changes are imminent in perfusion analysis and flow imaging.

Speed

Today's CMR is fast and continues to accelerate. The increase in speed is due to two changes. Firstly, with increasing capabilities of navigator sequences data acquisition has become less dependent on breath holding. Navigator sequences used to be slow, unpredictable and frequently of low quality. This was mainly due to the imperfect estimation of cardiac displacement based on measurements of the right hemidiaphragm and – as a result of the suboptimal correction of breathing motion – the rejection of a large proportion of the data acquired. Novel image navigators use the true position of the heart, yielding a much better correction for cardiac displacement during breathing allowing to increase scan efficiency to nearly

100% [7]. This efficiency may make navigator sequences faster and more patient friendly than breath holding for routine scanning in the very near future.

Secondly, the amount of redundant data acquisition is reduced. Changes such as parallel imaging have altered cardiac imaging strategies dramatically, as they allow a majority of acquisitions to be performed within a single breath hold rather than requiring long scans averaged over multiple breathing cycles. Compressed sensing now allows squeezing 3D volumes into a single breath hold or a short navigator scan, finally making CMR a truly 3D (or 4D) method.

New applications

Novel abilities continue to emerge. This is partially a consequence of an increase in speed and the development of novel sequences. The greater speed allows transferring imaging methods to the heart, which were previously reserved for non-moving structures. An example is diffusion tensor imaging, which has been successfully used in the brain and other structures and starts to emerge as a cardiac option [8]. Novel sequences utilize contrast better than previous

Previously Professor Nagel was Chair of Clinical Cardiovascular Imaging, Head of the Department of Cardiovascular Imaging and Deputy Head of the Division of Imaging Sciences and Medical Engineering at King's College London as well as Honorary Consultant Cardiologist at Guy's and St. Thomas' Trust, London, UK. He has developed and tested new methods for improved diagnoses and has developed stress tests for magnetic resonance imaging, which are now in use worldwide. He holds several patents on imaging methods, and has authored more than 250 publications and 25 book chapters. Professor Nagel is known worldwide for his teaching abilities.

methods, as highlighted by the articles on QISS MRA, which generates unprecedented contrast in non CE MRA [9]. I am sure that coronary MRA will also challenge CTA in the next few years.

CMR in 2030

The trends described above are only a small proportion of the opportunities that will open up to us in the near future. Our approach to imaging will change drastically. Whilst an accurate prediction of the future is almost impossible, I'd like to present my vision of CMR in 2030. A glance back 15 years will remind us of the speed of change. In 2000, the newly-launched iMac boasted a quarter of RAM, a CPU with half the speed and about the same display matrix as a 2010 iPhone. And at about the same time in CMR we were replacing Turbo Gradient Echo with SSFP, testing the first perfusion sequences (with a single shared prepulse) and using large external optical disks to store the data. So, how do I think the next 15 years may pan out?

In my vision, diagnostic tools will have immediate public access. Medical care will be much less confined to hospitals or require doctors. People

will be able to scan their hearts (function, structure, blood flow, synchrony, coronary arteries, contractility, cardiac efficiency, cell size) in public diagnostic centres without referral. They will be checked for contraindications by an artificial intelligence (AI) robot. Additional modules can be added based on the findings. The data will be automatically analysed and compared to a large database of age-gender-ethnicity-height-weight-matched controls, people with similar co-morbidities as well as the person's own previous scans. The results will be available immediately and if any therapy is needed a further meeting with an AI robot will assess possible contraindications and co-morbidities. The person will then be issued with the ingredients for his home-based pill-printer: a software update will provide the correct medication on a daily basis. Some patients will still need to see a doctor, as the AI robot has not yet been FDA cleared for certain diseases where information remains insufficient for adequate algorithms.

Of course, all therapy will require accurate, quantifiable and reproduc-

ible diagnostics before approval by health insurers. Continuation of therapy will be only reimbursed if a therapeutic effect can be demonstrated by imaging. As an example, a quantitative analysis of myocardial ischemia will be required before any anti-anginal therapy or even revascularization is approved. Interventionalists will be required to follow the imaging guidance. More expensive drugs will only be reimbursed if shown to be effective in the specific patient.

Trials will require full phenotyping of participants before, during, and at the end of the study. Endpoints will increasingly be based on the underlying pathophysiology rather than symptoms, outcomes or consequences of disease.

These are just some examples of what may lie ahead. Does CMR have a role here? It's hard to tell, but to remain at the heart of developments in 15 years' time we need to pursue the following five strategies.

Firstly, we must continue the drive for speed. Speed reduces costs, provides access, generates large numbers and creates the convenience required for success.

Institute for Experimental and Translational Cardiovascular Imaging, DZHK Centre for Cardiovascular Imaging, University Hospital Frankfurt, Germany (Goethe CVI)

This new institute will provide a platform for interdisciplinary multimodality cardiovascular research. The institute is equipped with a state-of-the-art 3T MAGNETOM Skyra MR and a SOMATOM Force CT exclusively for cardiovascular research. It is situated on the campus of the University Hospital within the European Cardiovascular Science Centre, which also houses several excellent groups in

basic cardiovascular science. The Institute is embedded in and supported by the German Centre for Cardiovascular Research (DZHK), a cluster of 28 members with outstanding cardiovascular research capacities.

Strong connections with the clinical partners in the university hospital namely Prof. Dr. Andreas Zeiher (Cardiology, Angiology, Nephrology) and Prof. Thomas Vogl (Interventional and Diagnostic Radiology) provide access to patients, practical know-how, clinical equipment and support.

Secondly, we must become fully quantitative. This may not require everything to be measured in signal intensity units, but it does require everything to be measured in units that are reproducible, have normal ranges with small standard deviations and relate to the severity and extent of the abnormality. Quantification enables comparability, follow-up, assessment of therapeutic needs and success and replaces the human eye with all its limitations by a reliable system. This will require standardization, reduction of freedom in parameters and massive improvement in postprocessing software.

Thirdly, we must strive for evidence-based approaches and overcome the battles of turf and power for access and reimbursement. We need to bring highly qualified teams together to push the borders of technology and knowledge. Failing this, other techniques, markers or groups will provide the services that we could lead on.

Fourthly, we must share knowledge and empower the next generation [10]. Our strength will depend on our ability to provide rapid services to large populations.

Lastly, we must not think in silos. I believe that CMR has all the advantages required to be a core modality in the type of diagnostic center

I have described above (no ionizing radiation, 3D coverage, high spatial and temporal resolution, excellent soft tissue contrast, endless possibilities). However, there are other techniques and blood markers that may provide similar information. We should embrace these techniques to allow for true comparison of their relative values, strengths and weaknesses, and also to remain at the forefront of this knowledge. We need to ensure that we are the ones to train the AI robots, not the other way round.

Our goal remains to reduce the burden of cardiovascular disease. I believe that advanced imaging can play a major role in this goal. Together, we will be strong enough to make sure the therapies of the future (cardiac regeneration, cardiac rejuvenation, printable electronic membranes) will be based on diagnostic imaging before, during and after therapy, thus ensuring maximal benefit for our patients while remaining within the given financial framework.

I wish you an exciting and inspiring SCMR 2016.

With best regards



References

- 1 Case Report: Detection of Myocardial Changes in a Patient Undergoing Chemotherapy, Steve W. Leung, et al., University of Kentucky Medical Center, Lexington, KY, USA [in this issue].
- 2 Case Report: Myocardial Fibrosis in a Non-Ischemic Cardiomyopathy, Jeremy D. Collins, et al., Feinberg School of Medicine, Northwestern University, Chicago, IL, USA [in this issue].
- 3 Case Report: Clinical Usability of MyoMaps in Myocardial Infarction, Masashi Nakamura, Saiseikai Matsuyama Hospital, Matsuyama, Ehime, Japan [in this issue].
- 4 Case Report: Acute Myocardial Syndrome in a 37-Year-Old Patient with Severe Renal Impairment, Anna S. Herrey, et al., The Barts Heart Centre, London, UK [in this issue].
- 5 Puntmann et al., JACC Cardiovascular Imaging 2016, in press.
- 6 Hinojar R, Foote L, Arroyo Ucar E, Jackson T, Jabbour A, Yu C-Y, et al. Native T1 in discrimination of acute and convalescent stages in patients with clinical diagnosis of myocarditis: a proposed diagnostic algorithm using CMR. JACC Cardiovasc Imaging. 2015 Jan;8(1):37–46.
- 7 Self-Navigated Free-Breathing High-Resolution 3D Cardiac Imaging: A New Sequence for Assessing Cardiovascular Congenital Malformations, Pierre Monney, M.D. Division of Cardiology and Cardiac MR Center, University Hospital of Lausanne (CHUV), Lausanne, Switzerland [in this issue].
- 8 Cardiac Diffusion Tensor MRI Using SMS Acquisition with a Blipped-CAIPINH Readout, Choukri Mekkaoui, et al., Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA [in this issue].

Prof. Nagel also leads the new Clinical Interdisciplinary Cardiovascular Imaging Service provided by the Institute of Interventional and Diagnostic Radiology and the Clinic for Cardiology, Angiology and Nephrology. This interdisciplinary service allows for rapid translation of research findings into clinical routine and the transfer of clinical questions into research, and also provides a platform for truly interdisciplinary clinical training and service.



Institute for Experimental and Translational
Cardio Vascular Imaging
University Hospital Frankfurt

- 9 – Quiescent Interval Single-Shot (QISS) Lower Extremity MRA for the Diagnosis of Peripheral Artery Disease: Case Presentations, Akos Varga-Szemes, et al., Medical University of South Carolina, Charleston, SC, USA.
– Case Report: QISS MRA at 3T, Anna-Maria Lydon, et al., University of Auckland, New Zealand [both in this issue].
- 10 Cardiovascular Magnetic Resonance Teaching Network. Requirements for Simplified Distribution and Sustained Quality, Jeanette Schulz-Menger, et al., Charité Medical Faculty and HELIOS Clinic Berlin-Buch, Germany [in this issue].

Editorial Board

We appreciate your comments.

Please contact us at magnetomworld.med@siemens.com



Antje Hellwich
Editor-in-chief



Wellesley Were
MR Business Development
Manager Australia and
New Zealand



Sunil Kumar S.L., Ph.D.
Senior Manager Applications,
Canada



Reto Merges
Head of Scientific Marketing



Gary R. McNeal, MS (BME)
Advanced Application
Specialist, Cardiovascular
MR Imaging, Hoffman
Estates, IL, USA



Peter Kreisler, Ph.D.
Collaborations & Applications,
Erlangen, Germany

Review Board

Lars Drüppel, Ph.D.
Head of Processes, Systems, Portfolio

Shivraman Giri, Ph.D.
Collaboration Manager

Matthias Lichy, M.D., M.Sc.
Clinical Competence Center

Edgar Müller
Head of Cardiovascular Applications

Christian Schuster, Ph.D.
Product Manager Cardiovascular

Bruce Spottiswoode, Ph.D.
Collaboration Manager

Susanne von Vietinghoff
Global Segment Manager Cardiovascular MR

Heike Weh
Clinical Data Manager