Claudia Prieto received her Ph.D. from the Pontificia Universidad Católica de Chile in 2007. From 2008 to 2011 she was a Postdoctoral Research Fellow in the Division of Imaging Sciences at Kings College London, UK. In 2012, she joined the School of Biomedical Engineering at Kings College London as Lecturer where she is currently Professor in Medical Imaging. She is Professor and Director for Research and Innovation at the School of Engineering at Pontificia Universidad Católica de Chile.

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René Botnar received his Ph.D. from the ETH Zurich, Switzerland. From 1996 to 97 he was a Research Associate in the Department of Radiology at the University Zurich. In 1997, he joined the Cardiac MR Center at the Beth Israel Deaconess Medical Center and became its Scientific Director in 2003. He subsequently was appointed to Assistant Professor of Medicine at Harvard Medical School in 2004.

In 2005, Dr. Botnar accepted a Professorship of Biomedical Imaging at the Technische Universität München. At the end of 2007, he joined the School of Biomedical Engineering & Imaging Sciences at King's College London where he is currently Chair of Cardiovascular Imaging. In 2022 he joined Pontificia Universidad Católica de Chile where he is currently Director of the Institute of Biological and Medical Engineering. Dr. Botnar is a Fellow of the International Society of Magnetic Resonance Imaging in Medicine, the Society for Cardiovascular Magnetic Resonance, and the Institute for Advanced Study at the TU Munich. He was a board member of the Society for Cardiovascular Magnetic Resonance from 2008 to 2011 and currently is a co-organizer of the SMRA 2024 annual meeting. He is currently Associate Editor of the Journal of Cardiac Magnetic Resonance and has authored more than 320 peer-reviewed original papers, 50 review articles and 30 book chapters in the field of cardiac magnetic resonance. He also holds 12 patents and is an editor of a textbook on Cardiovascular Magnetic Resonance Imaging.

The Power of Collaboration

Dear Readers and Colleagues,

Welcome to London and this exciting new edition of MAGNETOM Flash, which is dedicated to the joint SCMR, EACVI and ESCR meeting. CMR 2024 convenes physicists, engineers, technologists, radiologists, cardiologists, and industry, under the theme 'The Global CMR Conference: Together – expanding CMR worldwide!'. This theme highlights one of the most distinct aspects of our community that has shaped the history of cardiovascular magnetic resonance imaging: the power of working together.

Since the early conceptualization of MRI in the 70's, through the acquisition of the first images of the heart anatomy in the mid 80's, to several breakthroughs to enable functional assessment and tissue characterization in the 90's and early 2000, and the further advances nowadays; the power of collaboration, interdisciplinary expertise and collective efforts has been fundamental in translating technical developments into meaningful clinical applications and wider clinical acceptance of cardiovascular MRI.

Collaboration between scientists and clinicians is fundamental to developing solutions that address technical challenges while meeting clinical needs. Long exam times, limited spatial and temporal resolution, limited 2D coverage, complex scan planning and the need for patient cooperation, are some of several remaining challenges in cardiovascular MRI. These technical and clinical challenges drive the development of exciting advances in terms of novel imaging sequences, motion correction and reconstruction approaches, novel exogeneous and endogenous contrasts, efficient scans, multidimensional and multiparametric sequences, as well as image processing and analysis, among others.

This scientist-physician collaboration is also fundamental to evaluate and validate these innovations, first in academic clinical settings, providing valuable feedback on the strengths, limitations, and potential clinical impact of the new techniques. Subsequent collaboration with industry

partners enables the translation of these innovations into tangible technologies, facilitating the validation of new techniques in various clinical settings and in different countries and continents. Finally, the expertise of industry facilitates scaling up innovations, quality control, and regulatory compliance, which is essential for the successful transition of scientific discoveries into commercially viable and widely accessible cardiac MRI technologies and to the establishment of evidence-based guidelines for clinical use.

In this issue of MAGNETOM Flash, we find an exciting collection of articles showcasing the power of interdisciplinary collaboration in pushing the boundaries of cardiovascular MRI.

One of the three main topics of this issue is whole-heart MRI[1], which has been one of the remaining challenges of CMR for many years and was born in the early 90s with the desire of imaging the coronary arteries non-invasively with high-spatial resolution as a non-invasive alternative to X-ray coronary angiography. While the first demonstration by Manning and Edelman et al. in 1991 employed breath-holding in concert with ECG triggered fat suppressed 2D gradient echo imaging subsequent approaches employed free-breathing 3D coronary MR angiography (CMRA) with a thin 3D slab approach in concert with magnetization transfer contrast or T2 preparation enabling the visualisation of the proximal left and right coronary arteries without the need of a contrast agent. These free-breathing approaches were made possible using respiratory navigators first proposed by Ehman et al. in 1989 which for the first-time enabled achieving sub millimetre in-plane spatial resolution not possible with breath holding. While still being the state-of-art today on most clinical systems, unpredictable long scan times, residual motion artifacts and limited spatial resolution have limited the successes of 3D whole heart until today.

The article by Kunze et al. describes a new framework that our group at King's College London developed and that addresses the shortcomings of the diaphragmatic navigator approach. This novel 3D whole heart MRI sequence consists of an image navigator (iNAV)[1] for "model free" respiratory motion correction, a spiral like Cartesian trajectory with golden angle increment enabling respiratory data binning, and a non-rigid motion corrected image reconstruction enabling 100% respiratory scan efficiency, predictable scan times and isotropic resolution of 0.9 – 1.2 mm^3 in a 5 to 10-minute scan. Moreover, to further simplify the scanning procedure and selection of the inversion delay an AI assisted placement of the imaging, shim and navigator volume have been developed by a team of Siemens Healthineers scientists enabling the automated detection of the quiescent phase of the cardiac cycle. To test the robustness of the new 3D whole-heart approach in different healthcare systems validation has been performed in 3500 real world patients in 18 imaging centres on 4 continents. The article demonstrates successful use of this novel approach to differentiate between myocardial infarction and fatty infiltration, identify potential ablation targets from 3D corridors of border zone tissue or the identification of coronary artery disease on sub-millimetre resolution 3D coronary MR angiograms. These achievements are a demonstration of the power of collaboration between MR physicists of and clinicians at the research stage, a demonstration of collaboration between academics and industry at the innovation and prototype implementation stage and finally the demonstration of collaboration between industry, academics, and clinical centres at the clinical validation stage. Despite all the greatness of modern technologies, human collaboration remains at the centre stage of any advance in knowledge and creation of innovative solutions, even more so in healthcare.

The second article of the 3D whole heart topic demonstrates the power of collaboration between Siemens Healthineers scientists and clinicians at a high-volume medical centre in Greece exploring the new whole-heart sequence for interventional planning in complex congenital heart disease patients or for pre-procedural non-invasive mapping of the arrhythmogenic substrate in patients with atrial fibrillation, in order to better guide ablations, and ultimately assessing post-procedural success. This study demonstrates that 3D whole-heart MRI not only can be used for improved diagnosis or treatment planning in CHD patients but also can simplify the scanning protocol, obviate the need for direct expert supervision and collectively shorten the scan time in these patients with often complex anatomies.

The last article on the topic 3D whole heart MRI demonstrates how the collaboration between Siemens Healthineers and the team at St. Francis Heart Hospital in New York led to a new application of the iNAV as a "fluoro trigger" where the iNAV is "misused" for monitoring the passage of contrast agent and to start the high resolution free-breathing 3D pulmonary angiography scan in which the iNAV is subsequently used in its indented form for respiratory motion correction and to achieve 100% respiratory scan efficiency. This last example demonstrates how the power of collaboration can unlock new applications by thinking out of the box. It is also a notable example of the way the MRI community has worked in the past 30–40 years, and which has kept our community so vibrant and innovative.

The second main topic of this issue is MR Angiography. From a collection of articles, I would draw attention to the article by Paul Finn and colleagues since it addresses another holy grail application in cardiac MRI, which is free-breathing multidimensional (space, time, and velocity) 3D imaging of pediatric patients[2] without sedation. Scanning these patients is very demanding due to the complex heart anatomy, the small size of the vessels and cardiac structure,

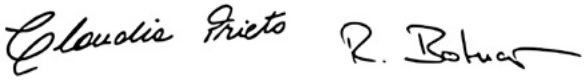
the high heart rates, and irregular breathing patterns. Typically, these exams require highly skilled teams with many years of experience, which usually are only available in advanced imaging centres in large metropolitan areas. In this study the UCLA team combines several ingredients such as

1) the use of a blood pool contrast agent, ferumoxytol[3] to prolong the imaging window and enable steady state imaging,
2) a novel free-running free-breathing self-gated 3D MRI sequence to obtain isotropic resolution multi heart phase images and
3) a compressed sensing accelerated 4D flow sequence[4] with diaphragmatic navigation.

The entire exam using this approach can be performed without breath holding and complex planning procedure and can be acquired in less than 30 minutes in comparison to the 60–90 minutes, which a complex CHD exam usually requires. What made this new exam possible is again the power of collaboration between scientists, industry, and clinicians. Each of the three ingredients of this CHD exam required several interdisciplinary teams to create innovative solutions. It also demonstrates that it takes many years of work to bring innovative ideas to fruition. Intravascular contrast agents were first proposed and demonstrated in clinical efficacy trials in the mid-90s, but it took almost 30 years until we start harvesting the fruits of this hard labour. Moreover, to fully exploit the potential of blood pool contrast agents it also required the development of free-breathing 3D whole-heart technology which equally almost took the same time to be ready for prime clinical use. One of the important lessons learned from the whole-heart articles in this MAGNETOM Flash edition is that collaboration allows us to move mountains and that we need to be persistent and patient to harvest the fruits of the challenging work, which is required to achieve ambitious goals.

The third main topic of this issue is cardiac imaging. An article that stands out is the BioMatrix Beat Sensor which enables cardiac MRI exams without ECG Leads. The Beat Sensor started as a curious engineering project within the Siemens Healthineers cardiac predevelopment team, but quickly developed into a hot topic as there was a clear clinical need for ECG lead less cardiac imaging due to difficulty of obtaining a good ECG trace in specific patient populations and due to the lack of highly trained cardiac MR technicians outside of academic clinical centres. The success of the BioMatrix Beat Sensor would again not have been possible without collaboration within Siemens Healthineers among engineers and the applications team and without the collaboration between Siemens Healthineers scientists and university academics and clinicians to demonstrate early in the development phase the true clinical potential of this unique and ingenious invention. The article by Mizuno and colleagues provides a good technical background into the working of the Beat Sensor and how its signal compares with the ECG signal for various cardiac diseases including hypertrophic cardiomyopathy, single ventricle, reduced LV ejection fraction, atrial fibrillation with low heart rates, atrial fibrillation with high heart rates, and pacing rhythm. The images presented are of excellent quality for a lead less scan and are very much comparable to ECG triggered cardiac scans. What makes this article special is the rapid clinical translation of a completely novel technology requiring new hardware and software in less than 10 years.

There are many more outstanding contributions in this issue of MAGNETOM Flash that we could not cover in this editorial, but we hope that the readers will enjoy this special SCMR 2024 edition, which highlights several progresses made since and thanks to the creation of our main scientific societies. This issue also highlights the power of CMR to be the ultimate cardiac imaging technology due to its unique potential to provide a fast comprehensive exam including radiation free assessment of anatomy, function, and tissue characterization in an ever-increasing spectrum of heart diseases. We hope you enjoy this issue as much as we did and hope to see you all during the CMR 2024 conference in London!



Claudia Prieto **René Botnar**

[1]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.
[2]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.
[3]Ferumoxytol is not approved for diagnostic applications and its use for MRI is off-label.
[4]The authors are using a non-product sequence, but 4D Flow has been available as a product since software version syngo MR XA30.