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Global Spotlights

Smart cardiac magnetic resonance delivering one-click and comprehensive assessment of cardiovascular disease

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The advent of invasive and non-invasive imaging tools in early phenotyping of disease, risk assessment, and therapy monitoring has transformed the pursuit of understanding and treating cardiovascular disease in ways previously unimaginable.[1] Among the powerful arsenal of imaging tools, cardiac magnetic resonance (CMR) imaging remains the only modality capable of providing a comprehensive assessment of the beating heart's function and anatomy without potentially harmful ionizing radiation. The undeniable safety of CMR is complemented by its ability to provide accurate 3D anatomic location and mapping of disease traits (e.g. scars), to offer a refined description of disease severity and subtypes, to quantitatively monitor disease progression, and more importantly to personalize patient management and optimize response to therapy.[2,3]

However, despite these unique strengths, CMR data acquisition, reconstruction, and analysis have largely remained unchanged over the past two decades. CMR being complicated by the complex anatomy of the heart and its vessels, as much as by cardiac and respiratory motion, acquisition of CMR images remains too slow (40–60 min), too complex (>400 mouse clicks for a CMR procedure vs. <30 for a brain scan), and the overwhelming amount of CMR sequences available makes this procedure poorly standardized and reproducible.[4–6] In addition, since clinical decision-making increasingly depends on quantitative metrics extracted from images, the interpretation of CMR studies requires extensive post-processing.[7] As image resolution and contrast remain suboptimal, the analysis is often not automated and has become the most complex step of CMR interpretation. These obstacles impose considerable patient cooperation and require highly trained specialists to capture, process, and interpret the images and, as such, have presented a barrier to a wider adoption of CMR. Consequently, unlike other imaging modalities such as echocardiography, CMR studies are expensive and poorly accessible, with patients often waiting several months to get a CMR scan, which can have deleterious effects on health outcomes.[8]

What has been holding us back is the fact that image acquisition, reconstruction, processing, and interpretation are four distinct domains requiring specific expertise (MR physics, mathematics, image processing, and medicine) that have been up to now mobilized in a sequential and non-integrated fashion. Novel intelligent technologies allowing for simple, rapid, and comprehensive imaging of the heart while delivering automated characterization of cardiovascular disease are urgently needed to take full advantage of CMR.

Given this context, the European Union under the Horizon 2020 research and innovation programme has funded the European Research Council Starting Grant 'smart cardiac magnetic resonance delivering one-click and comprehensive assessment of cardiovascular disease' (SMHEART). The aim of this research programme is to unleash the full potential of CMR to transform patient trajectories by introducing a fast, one-click, fully automated, and comprehensive imaging pipeline applicable to diagnosis, prognosis, and therapy selection in cardiology.

SMHEART will start mid-2023, for a duration of 5 years, and its aim will be achieved using a three-pronged approach (*Figure 1*): (i) creating a novel CMR technology that collects data in a single continuous free-breathing scan, taking into account post-processing requirements at the very origin of CMR sequence design; (ii) exploiting the unique contrasts generated by this technology to automatically extract quantitative markers on cardiac anatomy, function, and tissue characteristics; and (iii) translating this transformative technology from a pre-clinical to a clinical setting.

In the first work package, novel CMR sequences will enable 3D imaging of cardiac anatomy and function (cine), cardiac tissue mapping

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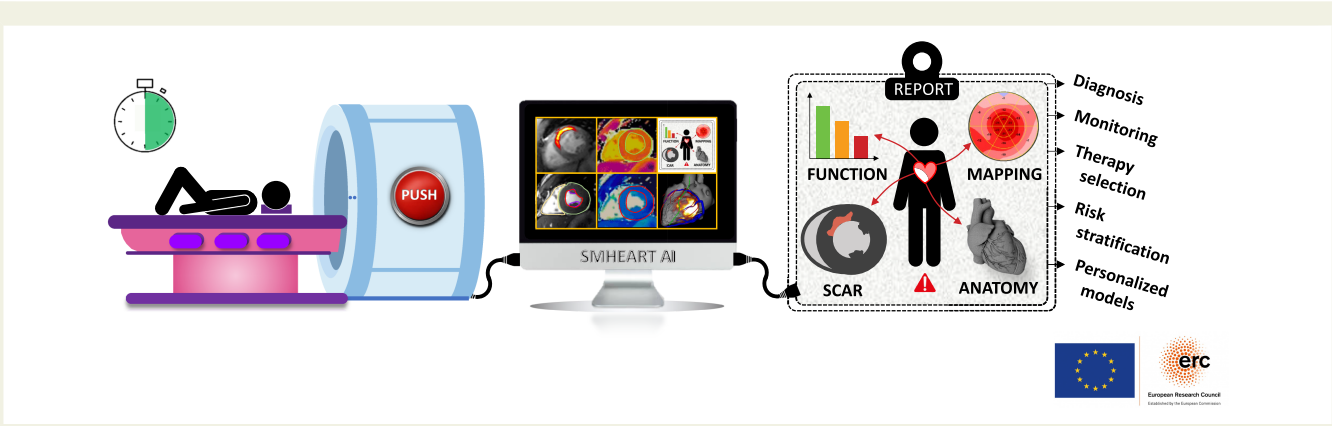

Figure 1 The cardiac imaging pipeline of the smart cardiac magnetic resonance delivering one-click and comprehensive assessment of cardiovascular disease project funded by the European Research Council under the European Union's Horizon 2020 research and innovation programme.

(T1/T2/T1-rho/extracellular volume fraction), and myocardial scars (with joint bright- and black-blood imaging) with minimal scan planning and patient cooperation.[9,10] The uninterrupted fashion of the sequences will eliminate the need for multiple highly specialized scans, whereas the black-blood technology will provide unprecedented contrast for automated analysis of myocardial injuries. In work package 2, the consortium will exploit the co-registered contrasts to automatically extract healthy and injured cardiac tissue parameters. Artificial intelligence tools, such as generative models and multi-view learning, will be exploited to perform automated diagnosis or to generate additional contrasts. Finally, these new technologies will be tested in a pre-clinical setting and in patients with structural heart diseases in work package 3.

The research will take place in France between Bordeaux University Hospital and IHU LIRYC—Electrophysiology and Heart Modeling Institute—a unique cardiology centre distinguished for its expertise in heart rhythm. Prof. Aurelien Bustin will co-ordinate the project, accompanied by Prof. Hubert Cochet (Radiology), Prof. Pierre Jaïs (Cardiology), Dr. Maxime Sermesant (Computer Science), and Prof. Matthias Stuber (CMR methods), who will act as consortium partners. The confluence of these five players, with their unique complementary skills, represents a fertile ground for innovation.

The proposed technology will disrupt a long-standing conundrum in CMR and will pave the way towards robust image-based strategies for personalized patient care (e.g. diagnosis, risk stratification, therapy selection, monitoring, and image-guided interventions). It will introduce a complete paradigm shift in CMR in which all cardiac characteristics are jointly represented in a single volume, allowing for a fully automated artificial intelligence-driven analysis. Novel contrast agent-free CMR methods will also pave the way towards screening of myocardial diseases in asymptomatic subjects. The method will unravel new pathophysiological mechanisms, owing to the intrinsic multi-parametric assessment of myocardial injuries. This may lead to knowledge discovery on the mechanisms of acute ischaemic and non-ischaemic injuries, scar ageing, or scar-related arrhythmogenicity. Finally, with minimal dependence on site-specific expertise, the method will be ideally suited for artificial intelligence applications in predictive medicine, leading to a better selection of patients to benefit from interventions (e.g. preventive defibrillator implantation, revascularization, resynchronization, or valve replacement).

Ultimately, the SMHEART technology will lead to faster exams, more patients scanned per day, improved patient comfort, and reduced operator dependency. This is paramount for the general adoption and wider dissemination of CMR.

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