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EDITOR'S COMMENT

Crown years for non-invasive cardiovascular imaging (Part III): 30 years cardiovascular magnetic resonance

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2013 is a remarkable year in cardiovascular medicine from a historical point of view. It can be considered a crown year for non-invasive clinical cardiovascular imaging as we can look back on 60 years of echocardiography, 40 years of nuclear cardiology, 30 years of cardiovascular magnetic resonance imaging, and 30 years of cardiac computed tomography. In previous Editor's Comments, 60 years of echocardiography and 40 years of nuclear cardiology were described (Parts I and II) [1, 2]. In this Editor's Comment (Part III) we will briefly look back to the roots of cardiovascular magnetic resonance imaging and its main achievements.

Cardiovascular magnetic resonance 30 years

The year 1983 was a major breakthrough for cardiovascular nuclear magnetic resonance (NMR). For the first time, various research groups around the world addressed the huge clinical potential of NMR in cardiovascular disease [3–7]. At that time, Burdine and Murphy (Texas Heart Institute, USA) stated that '*magnetic resonance cardiac imaging is an exciting new diagnostic modality in which acceptance as a routine diagnostic tool depends on the results of extensive clinical trials*' [7]. In order to eliminate the word 'nuclear', with its unpopular public connotation, the name was changed from NMR to MR imaging or MRI. Later on, cardiovascular MRI changed into cardiovascular magnetic resonance (CMR). Over the past 30 years, there have been major technical developments in CMR which have resulted in improved image quality allowing the accurate diagnosis and prognosis in patients with a wide spectrum of cardiovascular diseases such as coronary artery disease, cardiomyopathies, myocarditis, valvular heart disease, and congenital heart disease.

In 1984, the first CMR machine was installed in the Netherlands (Leiden). In the same year, first moving (cine) images of the heart by CMR were reported permitting the visualisation of wall motion abnormities [8]. CMR enabled the calculation of left ventricular volumes and ejection fraction [9], which turned out be accurate, reliable and reproducible [10]. In 1988, the Leiden group was one of the first to apply contrast-enhanced imaging using gadolinium-DTPA in patients following acute myocardial infarction [11]. The signal intensity ratio of infarcted versus normal myocardium was significantly greater after the administration of gadolinium DTPA improving the detection and localisation of infarct zones by CMR. From that moment on, myocardial tissue characterisation by virtue of contrast enhancement has obtained a fixed niche in CMR imaging [12–16]. In a landmark study using gadolinium-enhanced CMR in 50 patients with ventricular dysfunction, Kim et al. (Chicago, USA) showed that reversible myocardial dysfunction could be identified by contrast-enhanced CMR before coronary revascularisation [13]. The group directed by Sechtem (Stuttgart, Germany) showed that localised contrast enhancement was a frequent finding in the clinical setting of suspected myocarditis associated with active inflammation defined by histopathology [14]. Using contrast-enhanced CMR, the Amsterdam VUmc group directed by Van Rossum showed the presence of localised crypts in the inferoseptal left ventricular wall in patients with subclinical

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hypertrophic cardiomyopathy [15]. A recent study in patients with newly diagnosed non-ischaemic cardiomyopathy showed that contrast-enhanced-positive patients had a worse prognosis than patients without signs of contrast enhancement [16].

In the late 1980s CMR myocardial tagging was introduced, being a new alternative method for non-invasive assessment of myocardial motion. In addition to simple translation and rotation, complex motions such as cardiac twist and left ventricular torsion could be demonstrated [17, 18].

In the 1990s, CMR underwent further developments. In 1990, myocardial perfusion imaging by first-pass contrast-enhanced CMR was introduced based on the transit of gadolinium-DTPA through the cardiac chambers and myocardium [19]. After induction of vasodilation by either adenosine or dipyridamole, first-pass perfusion CMR imaging could be performed during intravenous bolus injection of a gadolinium-based contrast agent in order to detect perfusion defects in the ischaemic area [20]. In 1991, Manning's group (Boston, USA) was one of the first to show the potential of CMR imaging of the coronary arteries using breath-hold imaging techniques [21]. From that time on, coronary MR angiography allowed the detection of coronary artery stenosis [22]. In addition, it became possible to evaluate the functional status of coronary artery bypasses using high-resolution magnetic resonance angiography [23]. In 1992, Pennell's group (London, UK) reported the first use of left ventricular wall motion analyses during dobutamine stress CMR in 25 patients with exertional chest pain [24]. Dobutamine stress CMR was compared with thallium-201 single photon emission tomography (SPECT) showing a 90 % agreement between SPECT and dobutamine stress CMR for identifying myocardial ischaemia. In 1994, it was shown that dobutamine CMR clearly identified wall motion abnormalities by quantitative analysis using a modification of the centreline method, developed by Reiber's group (Leiden, NL) [25]. In one of the first prognostic dobutamine CMR studies, Kuijpers and Van Dijkman (The Hague, NL) reported a positive and negative predictive value of 95 % and 93 %, respectively, for identifying major adverse cardiac events by dobutamine CMR imaging.

Apart from its value in coronary artery disease, CMR has established a fixed niche in patients with structural and congenital heart disease [26–29]. Using velocity mapping techniques it was shown that CMR was well suited to detect changes in aortic stiffness by measuring distensibility and pulse wave velocity, for example in the Marfan syndrome [29].

From 2000 on, newer CMR techniques involving real-time imaging and 3-D data acquisitions with parallel imaging have increased efficiency in data acquisition. The increased availability of 3 Tesla MRI scanners provided an enhanced signal which increased the applications in general clinical practice [30–34]. Developments in contrast agents and molecular imaging agents further extended the potential applications of CMR. In recent years, CMR allowed the characterisation of plaque composition, i.e. the discrimination of lipid core, fibrosis, calcification, and intra-plaque haemorrhage deposits [35]. Identification of subclinical atherosclerosis and early treatment initiation has the potential to surpass conventional risk factor assessment and management in terms of overall impact on cardiovascular morbidity and mortality.

In summary, over the past 30 years CMR has evolved into an extremely useful diagnostic modality in cardiovascular disease. It offers new insights into cardiac pathophysiology and aids in the diagnosis of a wide spectrum of cardiovascular diseases. Although a single CMR exam may provide a comprehensive assessment for aetiologies of various cardiovascular diseases, hybrid imaging may become more informative and cost-effective in the long run [36–39]. With expanding expertise and recognition of its diagnostic and prognostic power, CMR will grow in importance in the armamentarium of the cardiac imager for years to come.

N.B. This Editors comment highlights only a selected number of achievements in CMR. For a more detailed description of the achievements by CMR the reader is referred to more in-depth publications [40–43].

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