Clinical advances in cardiovascular magnetic resonace imaging and angiography

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Issue Date: 2018-05-17

Chapter 1

General introduction and outline

Background

Over the last decades, Cardiovascular Magnetic Resonance (CMR) imaging has evolved into an accurate and reliable imaging modality for the radiologist to be used in clinical practice and research. CMR imaging is a noninvasive imaging technique providing invaluable information to evaluate the cardiovascular system without the need of ionizing radiation.[1]

In the early days of magnetic resonance imaging (MRI), imaging was performed on magnets with low field strength (for example 0.35 and 0.5 Tesla (T)). Nowadays in clinical routine, CMR is performed on 1.5T systems and high-field strength 3T whole-body MRI scanners have been introduced in clinical practice over the past few years.

The potential benefit of 3T MRI is providing images with increased signal-to-noise ratio (SNR) when compared to 1.5T.[2] High-field MRI systems enable acquisition with higher spatial resolution within a similar imaging time. Advances in MRI hardware and software technology have improved image quality enormously.

Whereas CMR was firstly used as an added imaging evaluation possibility for some patients in selected centers, additional to conventional techniques such as echocardiography, X-ray, or digital subtraction angiography, it has developed into an established first-in-line imaging modality in diagnosis, patient work-up and treatment planning for various cardiac and vascular diseases.

For cardiac imaging, CMR imaging has become a gold standard for evaluating ventricular volumes and function[3] and for imaging of myocardial infarction and viability.[4] It's noninvasiveness and radiation-free nature are important benefits for patients, especially in young patients or when serial follow-up is requested.

Image acquisition can be acquired with two-dimensional (2D), three-dimensional (3D) or four-dimensional (4D), when a 3D volume dataset is obtained in time-resolved manner. Thereby providing the opportunity for unlimited access of arbitrary imaging planes for accurate evaluation and quantitation. These are important advantages of CMR imaging over for example echocardiography as imaging is not hampered by the availability of acoustic windows.

The use of contrast agents plays an important role in CMR imaging. Especially, the value of delayed-enhancement imaging of myocardial scarring and viability in ischemic heart disease is well recognized and has gained widespread acceptance in daily practice.[5,6] Delayed-enhancement CMR imaging provides the opportunity to evaluate the transmural extent of infarcted myocardium with superior spatial resolution when compared to nuclear medicine techniques and improved diagnosis is to be expected.[7,8] Delayed-enhancement imaging requires multiple long breath holds from patients, which especially for patients with heart disease could be an important limitation. Free-breathing alternatives were very much desired and in this thesis, the application of one such approach is explored.

Contrast agents play also an important role in MR angiography (MRA). The paramagnetic behavior of a contrast medium injected in the blood pool and imaged with a whole body MRI system will result in a high contrast in signal intensity between the blood vessel and its surrounding tissue. In clinical routine, contrast-enhanced MRA (CE-MRA) is widely used for diagnosis and treatment planning in patients with peripheral arterial occlusive disease. The field strength of the MRI scanner is crucial in creating this contrast in signal. In this thesis, the performance of a high field strength system (3T) is being compared to 1.5T MRI with conventional digital subtraction angiography (DSA) serving as standard of reference.
Administration of MRI contrast agents can - although uncommon - cause allergic reactions and the association with adverse events, especially serious incidents with nephrogenic systemic fibrosis in patients with renal failure, have been reported in recent years.[9,10] Therefore, alternative imaging biomarkers in patients with peripheral arterial occlusive disease that can be obtained without the use of contrast agents need to be considered. Arterial wall thickness and stiffness are relatively new imaging biomarkers that can be obtained from non-contrast CMR, which may have prognostic value when evaluating the severity and progress of atherosclerosis. In this thesis, the value of these biomarkers will be assessed with non-contrast CMR for risk assessment and prediction of outcome in patients with peripheral arterial occlusive disease.

Outline of the thesis

Chapter 2 provides an introduction to cardiac MRI with special focus on the assessment of normal cardiac anatomy. The planning of the specific cardiac MR imaging planes is described along with an illustrative description of the normal cardiac anatomical structures that are visualized on CMR images. Additionally, some aspects of cardiac imaging on (ultra-) high-field MRI are addressed.

In **chapter 3**, the assessment of myocardial scarring with delayed-enhancement imaging is compared in a free-breathing protocol versus a sequence which uses breath-holding.

Chapter 4 describes various techniques that are currently available and applied for MRA. Furthermore, several anatomical regions that are imaged by MRA are addressed and the state-of-the-art is discussed, with special focus on the carotid arteries, thoracic and abdominal aorta, renal arteries, mesenteric artery, and the peripheral arteries.

Chapter 5 and **6** evaluate the diagnostic accuracy of single-injection, three-station, moving-table CE-MRA with high spatial resolution in patients with peripheral arterial occlusive disease (PAOD) at 1.5T and 3T, respectively. In **chapter 5**, the use of sensitivity encoding and random central–k-space segmentation in a centric filling order is evaluated with conventional DSA serving as the standard of reference. In **chapter 6,** single-injection, three-station, moving-table CE-MRA at 3T is compared to 1.5T CE-MRA. Also in this study, DSA is used as the standard of reference

Chapters 7 and 8 evaluate new imaging biomarkers for the severity of atherosclerosis which can be obtained without the use of contrast agents. In **chapter 7,** the associations between aortic wall stiffness, expressed by the pulse wave velocity (PWV) and sampled in various areas of the aorta, the arterial wall thickness, sampled in the common carotid artery, and the severity of PAOD, are evaluated.

Chapter 8 explores the prognostic value of outcome of these CMR imaging biomarkers in the patient populations with symptomatic PAOD in comparison with traditional risk factors (age, gender, BMI, hypertension, diabetes mellitus, levels of triglyceride and HDL in blood plasma samples, ABI and Fontaine class) over a follow-up period of six years.

Finally, in **chapter 9**, the conclusions are summarized.

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