i-T2prep: Flow-independent 3D whole heart vessel wall imaging using an interleaved T2-preparation acquisition

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INTRODUCTION: Bright-blood coronary magnetic resonance angiography (MRA) has shown great potential for the non-invasive assessment of intraluminal coronary artery disease, but angiography provides limited information on the magnitude of underlying atherosclerotic plaque. Recent studies using Multi-Slice Computed Tomography (MSCT)(1) and Intravascular Ultrasound (IVUS)(2) have shown that the culprit lesion in patients with ACS demonstrates extensive outward remodelling as well as CT and ultrasound attenuation compared to those with stable angina (3). These findings suggest that direct plaque visualization may have the potential to identify patients with a high risk of future coronary events and thus may help to better guide medical and interventional therapy (4). Black-blood MRI techniques have been successfully applied to visualize the vessel wall of the aorta, carotid and coronary arteries (5,6). The main limitation of these techniques is that they rely on blood flow. In this work we propose a novel technique for *flow-independent* vessel wall imaging, which takes advantage of the differences in T2 relaxation time of arterial blood and surrounding tissues using a T2 preparation prepulse (T2prep) (7). **METHODS:** The main characteristic of the T2prep prepulse is that it increases contrast between arterial blood and myocardium (and vessel wall) based on their T2 differences ($T2_{arterial\ blood}$=250, $T2_{myocardium}$=50ms). Signal from tissues with a shorter T2 relaxation time decay faster while signal from tissues with longer T2 will be maintained. Because arterial blood has a long T2, its signal only decays slowly while signal of muscle and the vessel wall decays more rapidly. Subtraction of two data sets, one obtained with T2prep(+) and another without T2prep(-) allows minimizing the signal of arterial blood while maintaining the signal of muscle and vessel wall. A weighted subtraction allows to completely nulling the arterial blood signal (Figure 1). One of the main challenges of this approach was to minimize the spatial misregistration in the subtracted images. In order to address this problem we developed an interleaved acquisition (i-T2prep) (Figure 2). In this case, the two sets of images are acquired interleaved, with the T2prep(+) performed every even heart beat (AQ1, Figure 2) and the T2prep(–) every odd heart beat (AQ2, Figure 2). A simulation of the longitudinal magnetization for different tissues after direct and weighted subtraction and for different T2prep durations is shown in Figure 3. The maximum contrast between muscle and arterial blood is reached at a T2prep duration of 80 ms; Figures 3e-f show the expected contrast between arterial blood, vessel wall (muscle) and epicardial fat in the directly and weighted subtracted images demonstrating the feasibility to null the arterial blood magnetization Mz while maintaining the magnetization of the arterial vessel wall. The i-T2prep sequence was implemented on a 1.5T Achieva Gyroscan MR scanner (Philips Healthcare, Best, NL) equipped with a 32-channel receiver coil. First, we validated the i-T2prep technique against a rapid black blood Double Inversion Recovery (DIR) vessel wall sequence in the thoracic aorta of 8 healthy subjects. We then acquired i-T2prep whole-heart images in the same subjects to obtain coronary vessel wall images of both the right and left coronaries arteries and we also acquired a right coronary artery (RCA) targeted i-T2prep scan to demonstrate targeted vessel wall imaging. **RESULTS**: We successfully obtained black blood vessel wall images of the thoracic aorta and coronary arteries. Representative T2prep(–) and T2prep(+) and subtracted images of the thoracic and reformatted images from whole heart of the right and left coronary artery are shown in Figures 4 and 5. **CONCLUSIONS:** We present a new approach for flow-independent vessel wall imaging. The main advantages of the i-T2prep sequence are its large 3D coverage and insensitivity to blood flow. This approach is easy to implement and has the additional advantage that it can be combined with a whole-heart protocol making clinical translation more attractive.

Figure 1- Schematic representation of the *i-T2prep* Sequence Without T2prep = T2prep(-) and with T2prep = T2prep(+).

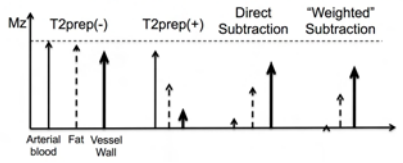


Figure 2- Interleave acquisition (*i-T2prep*). T2p: T2preparation, FS: Fat Saturation N: Respiratory navigator. AQ: Acquisition window

Figure 3- Simulation of the Mz magnetization for different tissues of the dynamic T2prep for different T2prep durations (TEff). (a) Mz before the imaging sequence when T2prep(+) (b) Mz when T2prep(-). (c) Difference between T2prep(-) and T2prep(+). (d) Magnetization after subtraction for optimal T2prep duration of TE=60 ms.

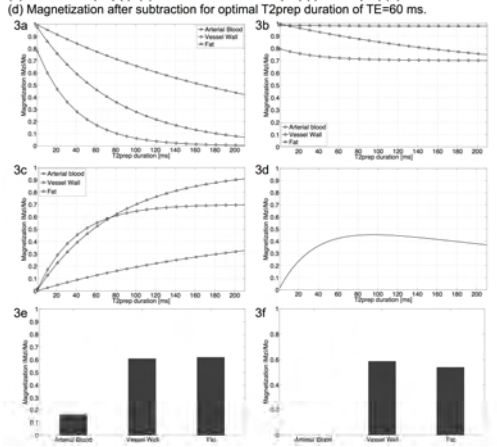


Figure 4- Aorta i-T2prep vs DIR Zoom acquisition. (a) T2prep(-), (b) T2prep(+), (c-d) directed and weighted subtracted images, (e) DIR-Zoom

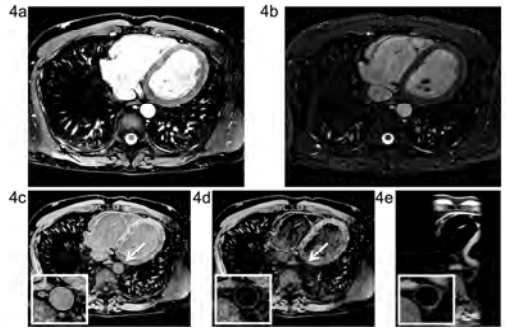
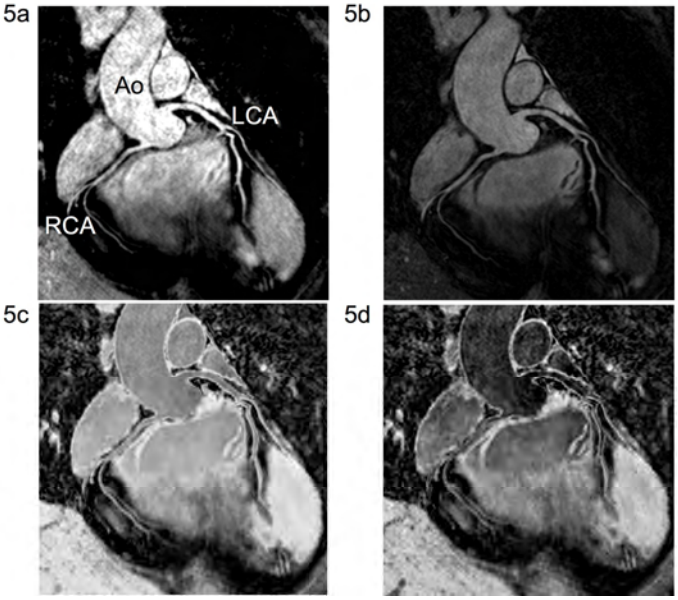


Figure 5- Reformatted images from a whole heart acquisition using the *i-T2prep* (a) T2prep(-), (b) T2prep(+), (c-d) directed and weighted subtracted images



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