3D Coronary Vessel Wall Imaging with a Local Inversion Technique and Spiral Image Acquisition

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Introduction

Coronary MRA has shown great potential for non-invasive assessment of the lumen of the coronary arteries (1), but it does not provide any information on the presence or magnitude of atherosclerotic plaque. It is also known that approximately 60-70% of acute coronary syndromes are caused by < 50% luminal diameter stenoses (2). Thus, a non-invasive approach for coronary plaque imaging would be desirable. Recently, MR coronary vessel wall and plaque imaging using dual inversion (Dual-IR) 2D fast spin echo techniques have been reported. It could be demonstrated that respiratory motion artifacts can be minimized by the use of breathholding or respiratory navigators and that both techniques allow for direct assessment of coronary wall thickness and the visualization of atherosclerotic plaque (3-6). However, for clinical use, 3D approaches would be more favorable as they allow for a more extensive coverage of the coronary artery tree and they offer the potential for higher spatial image resolution. The combination of a 3D-acquisition technique together with a Dual-IR pre-pulse can decrease the effectiveness of the Dual-IR preparation, thereby decreasing the black blood properties. We therefore implemented a 2D selective local inversion pre-pulse, which preserves the signal from the area of interest while minimizing unwanted signal from adjacent tissues and blood. We hypothesize that this approach allows for 3D black blood coronary vessel wall imaging.

Methods

Free-breathing 3D coronary vessel wall imaging using a local inversion technique and spiral image acquisition was implemented on a commercial Philips Gyroscan ACS-NT MR scanner (Philips Medical Systems, Best, NL) equipped with PowerTrak 6000 gradients (23mT/m, 219µs rise time). Four healthy adult subjects without clinical history of cardiac disease were examined in supine position using a 5-element cardiac synergy receive coil and a cardiac software package (INCA2). All vessel wall scans were done during mid-diastole and free-breathing. The right coronary artery was identified using a fast double oblique navigator gated 3D TFE/EPI scan (7), which was then subsequently used for planning of the 3D black blood local inversion vessel wall scan (Figure 1).

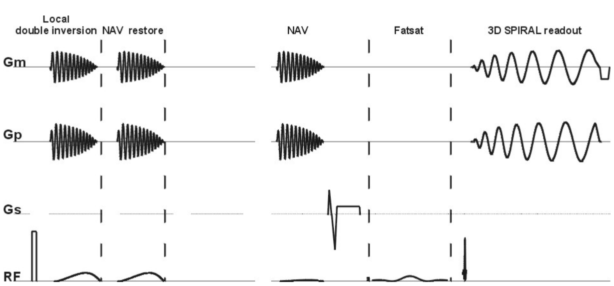

Fig1: Schematic of a 3D spiral black blood vessel wall sequence using a local inversion pre-pulse.

A non-selective 180° inversion pre-pulse was immediately followed by a 2D selective 180° local inversion pre-pulse (diameter=30mm), which was planned along the path of the RCA, approximately perpendicular to the 3D imaging volume. To facilitate navigator detection on the right hemi-diaphragm (RHD), a 2D selective 180° navigator restore pulse was used (8). After the inversion time TI=T1*ln2-T1*ln(1+exp(-2*TRR/T1)) (9), a 3D spiral imaging sequence was applied, which was preceded by an RHD navigator (5mm gating window) and a frequency selective fat suppression prep-pulse. The imaging sequence consisted of one (α=90°) or two (α=45°, 90°) (10) spiral interleaves per every second cardiac cycle (23ms per interleave, TE=2ms, TR=30ms) resulting in an acquisition window of 30-60ms. In 336 cardiac cycles, 6/12 slices with a reconstructed slice thickness of 2mm and an in-plane spatial resolution of 0.66*0.66mm (FOV=340mm, matrix=512*512) could be acquired.

Results

In all subjects, the 2D selective inversion pre-pulse suppressed unwanted signal outside of the locally inverted region of interest while preserving the signal in the user selected circular area around the coronary vessel wall (Figure 2a). Cardiac and respiratory motion artifacts were minimal due to the strong suppression of signal from myocardium, ventricular blood and the chest wall. Definition of the coronary artery wall and suppression of coronary blood were excellent in the whole 3D dataset (Figure 2b-g). No labeling artifacts from unwanted signal of ventricular or coronary blood, as often present in 3D Dual-IR coronary vessel wall scans were observed.

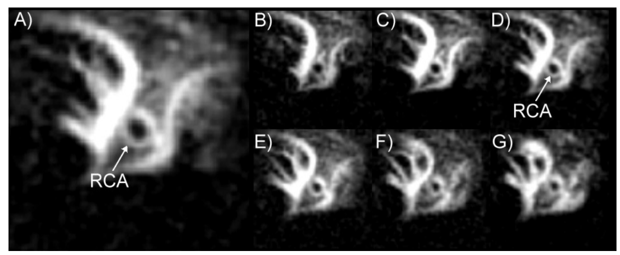

Fig2: 3D dataset (B-G) of the proximal RCA wall. Magnified view (A) of slice (D).

Discussion

We successfully demonstrated the feasibility of free-breathing 3D coronary vessel wall imaging in humans. The local inversion technique helped reducing cardiac and respiratory motion artifacts due to the strong suppression of signal from ventricular blood and the chest wall. Furthermore, it enables 3D "black blood" coronary vessel imaging as the local inversion pulse does not re-invert left ventricular blood, which subsequently could enter the 3D imaging volume and decrease the contrast between coronary blood and the coronary vessel wall. The ability to acquire 3D datasets of the coronary vessel wall combines the benefits of a more complete coverage of the coronary artery tree together with the potential for increased spatial image resolution. The use of a spiral acquisition scheme is advantageous because of the short acquisition window, which helps minimizing cardiac motion artifacts and it also offers a relatively high SNR per unit time.

We conclude that 3D coronary vessel wall imaging in combination with a local inversion technique might have a potential for screening coronary artery segments with luminal narrowing. This method would be also beneficial to investigate subclinical disease and coronary remodeling after pharmacological intervention in-vivo.

References

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