Impact of Preparation Phases on Vessel Wall Imaging Using Spiral Image Acquisition at 3 Tesla

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Introduction: Coronary vessel wall imaging with MR has the ability to obtain vessel wall thickness and lumen diameter non-invasively (1,2,3). Apart from cardiac and respiratory motion, a major challenge of coronary vessel wall imaging is their relatively small thickness (0.5-2mm) and thus the need for high resolution. With the wider spread availability of high field 3T clinical scanners higher resolution coronary vessel wall imaging has become more feasible. A previous pilot study using a 3T system has shown a gain in SNR of about 50% compared with results obtained at 1.5T (4). The use of more SNR-efficient spiral sequences together with the local inversion technique would combine the advantage of high field MRI with the ability of 3D imaging of the coronary vessel wall. The main challenge to be overcome is the increased field inhomogeneity ($\Delta f0$) at 3T, which especially may hamper the use of spiral imaging due to its sensitivity to off-resonances. Therefore the preparation phases for determining the correct f0 and shim values are of high importance. In particular, f0 may also vary throughout the cardiac and respiratory cycle, requiring triggered shimming and f0 determination. In this study we sought to optimize the local inversion pre-pulse technique together with spiral image acquisition for 3T systems and investigated the impact of the f0 and shimming trigger delay on image quality. We also investigated the effects of small long-term drifts in the magnet field strength that may affect fat sat (SPIR) performance by performing a f0 shift calibration during the preparation phase.

Methods: Free-breathing coronary vessel wall imaging using a local inversion technique and spiral image acquisition was implemented on a 3T Philips Achieva clinical scanner. Four healthy adult subjects without clinical history of cardiovascular disease were examined in supine position using a 32-element cardiac coil. The local inversion prepulse was applied immediately after the R-wave and imaging data were acquired in mid-diastole. This allowed taking advantage of rapid early systolic right coronary artery (RCA) flow (maximum blood exchange) while maintaining black blood properties. A coronary angiogram of the RCA was used to plan the local inversion black blood 3D vessel wall scan. A non-selective 180° inversion pre-pulse was immediately followed by a 2D selective 180° pencil beam local inversion pre-pulse (diameter=35mm), which was planned along the path of the RCA, approximately perpendicular to the 3D imaging volume. A 2D selective 180° navigator restore pulse was applied to facilitate navigator detection on the right hemi-diaphragm (RHD). The inversion time of approximately 600-700ms was sufficient to allow for complete blood exchange in the imaging volume and was followed by a 3D spiral imaging sequence, which was preceded by a RHD navigator (5mm gating window) and a chemical shift selective (SPIR) fat suppression prepulse. The imaging sequence consisted of 1 spiral interleave (flip angle=45°) per every other cardiac cycle (acquisition window = 21ms). In 56 cardiac cycles (100% navigator efficiency), 1 cross-sectional slice with a slice thickness of 8mm and a measured in-plane spatial resolution of 0.60x0.60mm (FOV=220mm) could be acquired. Total imaging time was between 1:30 and 3 minutes depending on the heart rate and navigator efficiency. We obtained images with both a default (330ms) and a subject specific trigger delay for shimming and f0 determination.

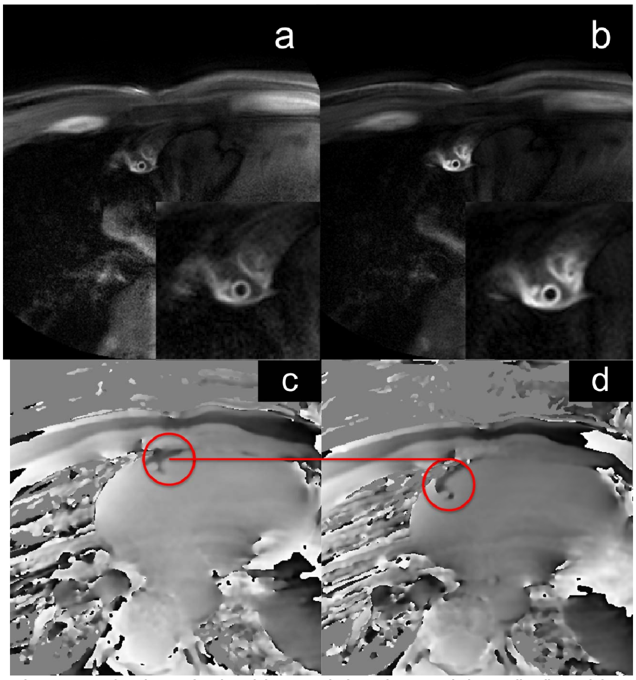

Figure 1: (a,c) Default shim and f0 trigger delay, (b,d) subject specific shim and f0 trigger delay. In both cross-sectional right coronary artery scans (a and b) the vessel wall is well defined, however there is clearly less signal in scan a. The B0 phase maps (c and d) acquired in the same plane as the vessel wall images show a large displacement in the position of the artery.

Results: In all subjects the right coronary vessel wall could be successfully visualized and in two out of four subjects the adjustments in trigger delay for shimming and f0 determination during the preparation phase resulted in a higher vessel wall signal (Fig. 1a-b). The movement involved in the period between the default and adjusted trigger delay is visible in B0 phase maps of both trigger delays (Fig. 1c-d) resulting in slightly different B0 values. In 3 subjects, an f0 shift calibration during the preparation phase was useful to obtain better-defined and higher signal vessel wall images (Fig. 2).

Conclusion: To obtain well-defined, high signal and high-resolution coronary vessel wall images with spiral image acquisition at 3T, ECG triggered shimming and f0 determination performed during the quiescent phase of the cardiac cycle seems advantageous. Furthermore, correction for small long-term drifts was beneficial for obtaining coronary vessel wall images with improved image quality. To account for f0 changes due to respiratory motion a navigator gated preparation phase may be useful and will be investigated in future studies.

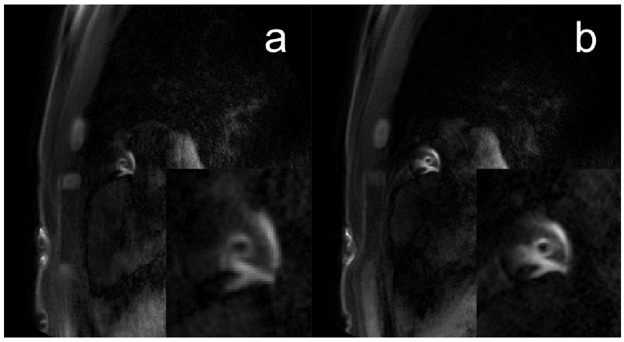

Figure 2: (a) no f0 shift calibration, (b) f0 shift calibration. The vessel wall image without f0 shift calibration is slightly blurred and has lower signal than the image where drifts in f0 are corrected.

(1) Fayad ZA et al. Circulation 2000; 102:506-510, (2) Botnar RM et al. Circulation 2000; 102:2582-2587, (3) Botnar RM et al. MRM 2001; 46:848-854, (4) Botnar RM et al. JCMR 2003, 5.4:589-59