3D Coronary Vessel Wall Imaging at 3 Tesla using DIR with an Obliquely Oriented Re-inversion Slab

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Introduction

Coronary vessel-wall imaging can detect wall thickening due to atherosclerosis [1] which presents clinical risks even when there is no lumenal stenosis which could be detected using angiography. Increased SNR is desirable due to the high resolutions needed and can be achieved using either increased field strengths (3T) [2] or 3D imaging [3] (which also allows volumetric coverage) but these methods have not so far been combined.

The blood signal is suppressed using double inversion recovery (DIR) which relies on the inflow of inverted blood from outside the imaging volume during the inversion time (TI). To suppress blood effectively with 3D imaging, it is important to avoid re-inversion of blood in the left ventricle (LV), which is upstream of the coronary arteries. At 1.5 T, this has been achieved using a 2D RF pulse to re-invert a localised cylindrical volume [3]. However, such pulses are sensitive to inhomogeneities in the main field B_0 which are increased at 3T; furthermore these and other non-adiabatic pulses give suboptimal inversions at 3T due to flip-angle inhomogeneities. These effects can particularly affect the diaphragm region where the respiratory navigator beam is positioned, thus compromising the motion compensation and reducing image quality. In this work, we therefore use a slab-selective re-inversion, with oblique orientation to avoid re-inversion of LV blood; this allows DIR to be implemented using robust adiabatic pulses, to avoid problems with inhomogeneous B_0 and B_1 fields. Using this method we demonstrate the feasibility of 3D coronary vessel-wall imaging at 3 Telsa.

Methods

Black-blood imaging of the right and left coronary arteries was performed at 3T. DIR used adiabatic pulses (hyperbolic secant, 12 ms duration, 1020 Hz bandwidth). However, the selective re-inversion pulse was applied to an obliquely oriented slab, instead of to the imaging volume. The slab was positioned by the user (red slab in Fig. 1) including the desired artery where it intersected with the imaging volume, but excluding the respiratory navigator and blood upstream from the RCA, particularly in the LV. Phantom experiments (not shown) demonstrated that, at 3T, the adiabatic DIR prepulses gave superior performance to the previous method [3] in both imaging and navigator regions.

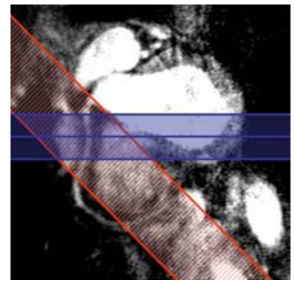

Fig. 1: Positioning of re-inversion slab (red) and imaging volume (blue) for in-plane RCA scan.

20 healthy volunteers (mean age 26) were scanned with a 3T Intera system (Philips Medical Systems) using a 6-channel cardiac coil and vector-ECG triggering, after giving informed consent. Images were acquired with a 3D turbo-field echo (TFE) sequence (flip angle 30°, turbo-factor 8 in partition direction) during free breathing and using prospective navigator gating. The cardiac trigger-delay was set to mid-diastolic diastasis. The navigator beam was placed on the right hemi-diaphragm, using 9 spiral turns and 40 mm beam diameter; a 2D navigator-restore pulse was applied immediately after the DIR pulses. Fat suppression pulses were applied before the navigator and the TFE readout.

Cross-sectional scans were acquired with: TE/TR = 2.6/8.6 ms; matrix 512×358×6; acquired resolution 0.66×0.66×4.0 mm^3; shot interval 1 heartbeat; scan-time 504 heartbeats. In-plane scans were also acquired with TE/TR = 2.4/7.8 ms, matrix 512×307×6, acquired resolution 0.7×0.7×2.0 mm^3; shot interval 2 heartbeats; scan time 616 heartbeats (scans times assume 50% navigator efficiency).

Signal-to-noise and contrast-to-noise ratios were measured for each dataset using ImageJ (NIH). For the cross-sectional scans, vessel areas, lumen diameter and wall thickness were measured. Qualitative assessments of image quality were made by two observers in consensus (scale 1–5 for cross-sectional images, and 1–4 for in-plane, highest is best).

Results

Fig. 2 shows in-plane images of the RCA, and Fig. 3 shows examples of cross-sectional images of the RCA and LAD. Table 1 gives details of measured SNR, CNR and qualitative assessments, while Table 2 details the measured vessel dimensions for cross-sectional scans.

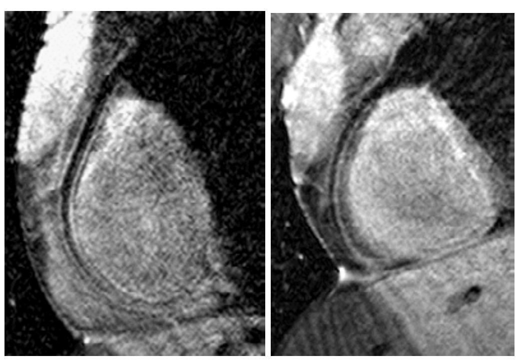

Fig. 2: In-plane vessel wall images from two subjects.

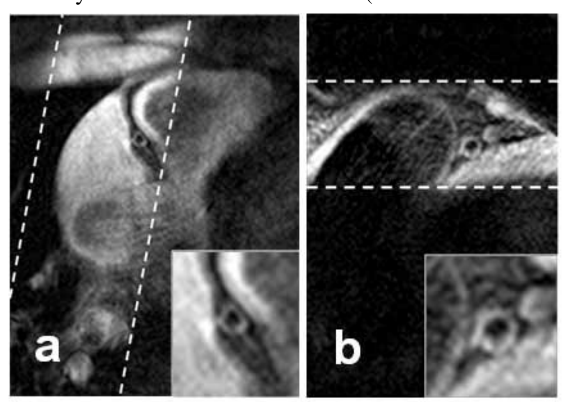

Fig. 3: Cross-sectional images of (a) the RCA and (b) LAD. Dashed lines show the position of the re-inversion slab and insets show vessel wall enlarged.

Discussion and Conclusions

The applied oblique re-inversion using adiabatic pulses allows good blood suppression and is robust against B_0 and B_1 inhomogeneities. It allows a good restoration of magnetisation in the navigator region, therefore avoiding adverse effects on image quality. Using this approach, we have demonstrated the feasibility of 3D coronary vessel-wall imaging 3T. The measured vessel wall thickness is consistent with previous work [1–3]. Although we have not directly compared our method in vivo with those published previously, the measured SNRs and CNRs are both high, as expected from our use of 3D imaging at high field strength. In future, image quality might be improved further using radial k-space trajectories, which are more robust against residual motion.

Orientation	Volunteers	Signal to Noise Ratio			Contrast to Noise Ratio		Image Quality (mean score)
		Vessel wall	Lumen	Fat	Wall-lumen	Wall-fat	
Cross-sectional	11	29.7 ± 7.5	10.5 ± 4.4	14.3 ± 5.2	19.2 ± 7.7	15.3 ± 8.1	3.7 / 5
In-plane	9	21.8 ± 7.5	7.1 ± 6.1	12.8 ± 5.1	14.7 ± 7.1	8.9 ± 4.9	2.1 / 4

Table 1: measured SNR and CNR, and qualitative analysis scores for the different scans.

Lumen diameter	Lumen area	Wall thickness	Wall area
2.5 ± 0.5 mm	5.0 ± 2.0 mm^2	0.9 ± 0.1 mm	9.9 ± 2.2 mm^2

Table 2: vessel dimensions for cross-sectional images.

Acknowledgement

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References

[1] Kim WY et al. Circulation 2002;106:296–9. [2] Botnar RM et al. J Cardiovasc Magn Reson 2003;5:589–94. [3] Botnar RM et al. Magn Reson Med 2001;46:848–54.