Reversed Spiral Imaging for Coronary MR Angiography

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Synopsis
Coronary MR angiography (CMRA) can benefit in the future from the principles of molecular imaging. Specific contrast agents will offer the opportunity to image arterial plaque directly, if appropriate image contrasts (T1 or T2*) can be introduced. Spiral imaging has been shown to be robust and efficient for CMRA, and reversed spiral imaging can generate strong T2* weighting. In this work, the applicability of free breathing, sub-millimeter 2D and 3D reversed spiral coronary MRA with strong T2* contrast was studied in the view of future contrast agent developments.

Introduction
CMRA showed significant progress during the last few years [1]. One of the advantages of cardiac MRI (including CMRA) is its great potential to manipulate image contrast according to the different diagnostic needs. Using appropriate spin preparation and scanning schemes, image contrast can be specifically tailored. Besides these conventional measures, contrast agents come into focus either to improve CMRA results or to perform molecular imaging [2], which offers the opportunity to image arterial plaque [3]. To introduce strong T2* contrast, which is e.g. necessary if USPIO based agents are used, reversed spiral imaging [4] can be employed, which samples k-space efficiently. Spiral scanning shows high robustness against flow and motion related artifacts [5], which is of advantage in CMRA. In the present work, the applicability of free breathing, sub-millimeter 2D and 3D reversed spiral coronary MRA with strong T2* contrast was studied.

Methods
Initial in-vivo experiments were performed on healthy adults using a 1.5 T whole body scanner (Gyroscope, ACS-NT15, Philips Medical Systems) and a single circular receive coil (Ø 20 cm). Coronary MRA was studied using magnetization prepared [6] 2D and 3D spiral imaging [7] (T2-preparation TE 50 ms, regional signal pre-saturation (R) on the chest wall, fat suppression SPIR (F)). In 3D imaging, the signal was acquired using a stack-of-spirals approach [5] (voxel size 0.7 x 0.7 x 3.0 mm³). Using identical spin preparation, three different approaches have been pursued (c.f. Fig. 1), i.e. (a) a conventional single interleaved forward spiral (AQ window 20 ms, TE 2 ms) using a 90° excitation pulse [7], (b) two consecutive reversed spiral interleaves (AQ window 10 ms, TE 16 ms) using 45° and 90° flip angles and (c) a single interleaved reversed spiral (AQ window 20 ms, TE 26 ms) using a 90° excitation pulse. For the reversed spirals, first gradient moment nulling was applied to minimize flow related artifacts [4]. Each 2D (sub)k-space was traversed with variable angular speed using 40 (a,c) or 80 (b) interleaves and a 512 2 scan matrix. In 3D scanning, conventional phase encoding was applied for 10 slices. Image reconstruction was performed by gridding and Fourier transform. All spiral images were additionally corrected for spatial off-resonance blurring using a conjugate phase reconstruction [9] based on a measured field map. Real-time navigator gating (N) using a 5 mm acceptance window and prospective slice tracking was applied in all experiments.

Results
In all the measured volunteers and for all the different imaging techniques, the major parts of the proximal coronaries (RCA, LAD) could be visualized. All data sets, especially those with T2* weighting, show very high contrast between the arterial blood pool and the surrounding tissue. In Fig. 2, selected reformatted images of 3D data are shown for the three approaches. Despite the very high effective echo times, the reversed spiral data still show significant signal. Strong flow-related artifacts are visible in the ventricles, whereas these artifacts are not as pronounced in the coronaries. The visibility of these vessels (e.g. its length) in the heavily T2* weighted images is comparable with that acquired with the conventional forward scan.

Discussion and Conclusion
Using reversed spiral imaging, strong T2* contrast can be introduced into high-resolution coronary MRA data. Gradient moment nulling is essential to avoid flow related artifacts in this type of scanning. Reversed spiral imaging combines effective signal sampling properties with the ability for strong T2* weighting. It has the potential to allow visualization of signal voids caused by the application of future site-specific (e.g. plaque sensitive) contrast agents based on T2* contrast mechanisms. A combination of forward spiral sampling for high definition coronary MRA with reversed spiral sampling to reflect the influence of the potential contrast agents could be very interesting in the future.

References