Time-Resolved Whole-Heart Coronary MRA using a Very Small Iron Oxide Blood-Pool Contrast Medium

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Introduction

A large amount of time is necessary in coronary MRA (CMRA) examinations to set up the measurement of thin-slab volumes, targeted at each vessel. Signal-to-noise ratio is proportional to the square root of the number of excitations. It is thus advantageous to measure the whole coronary tree with one thick-slab than using multiple thin slabs (1). The use of T1-shortening blood pool contrast agents, in combination with inversion recovery preparation to generate better contrast between myocardium and blood and the whole-heart approach significantly improves image quality in angiograms (2). Still several breathhold measurements are required to determine the optimal trigger delay, which may vary for the different vessels. Multi-phase acquisition renders those scout scans unnecessary as well. Whole heart multi-phase gradient echo imaging generates pure T1 contrast without time consuming preparation.

Materials and methods

Studies were performed at 1.5 T. 8-15 phases were measured in the cardiac cycle, consisting of a navigator for prospective respiratory gating and slice repositioning (acceptance window 4 mm), followed by FAT-SAT, spoiling and 40-50 ms data acquisition with segmented 3D FLASH or spiral readout. As the anesthetised pigs were breathing every 10 s, a single navigator for all phases could be allowed, increasing the number of acquired phases to as much as 15 (temporal resolution 50-60 ms). For the FLASH readout, 5 segments per phase were measured with a bandwidth of 190 Hz/pixel, TE 2.3 ms, 20° flip angle, 160 mm FOV, 192 Matrix (0.75 PF). 70 images of 1.2 mm were interpolated from 56 partitions. With spiral imaging, three 12.3 ms segments per phase were acquired with TE 1.1 ms, 35° flip angle and 57 spiral interleaves per partition. The first phase in the cardiac cycle was measured with half the 3D resolution but two different TEs (1.1 & 2.0 ms) to generate fieldmaps for off-resonance correction. The in-plane off-centre shift of every interleave was retained as it changes due to slice repositioning and cannot be corrected with the receiver phase. The raw data were phase-corrected according to the individual shifts before gridding reconstruction. All animal experiments were approved by the responsible authority. The contrast agent, VSOP - very small super-paramagnetic iron oxide particles - are coated with a monomer (citrate) (3). The particles are characterized by a favourable ratio of T2- to T1 relaxivity in combination with a long blood pool half-life of 71 min at 60 µmol Fe/kg, which the pigs received.

Results

The new multiphase acquisition yields high contrast angiograms comparable to that of magnetization-prepared single phase measurements. There was no difference in SNR between spiral and FLASH acquisitions of equal measurement time and spatial resolution (Fig 1). Spiral images however showed some residual blurring in spite of frequency offset correction.

Discussion

The total scan time of this volume-covering time-resolved CMRA is on the order of 30 minutes. This is tolerable because of the reduced set-up time, but makes the method sensitive to long-term motion. There is no need for any additional magnetization preparation, neither inversion recovery nor T2-prep. This enables high temporal resolution, which could be further improved using sliding window reconstruction or shorter navigators than we did (e.g. fat navigators (4) or self-gating techniques (5)). Fat suppression benefits from multiple excitation and saturation pulses. Compared to SSFP techniques, the applied RF power is low and SAR is not a limiting factor. As a by-product, the methods yields morphometric and functional parameters with high precision. It requires a minimum of planning and leaves more time during an examination to improve the quality of the CMRA data set.

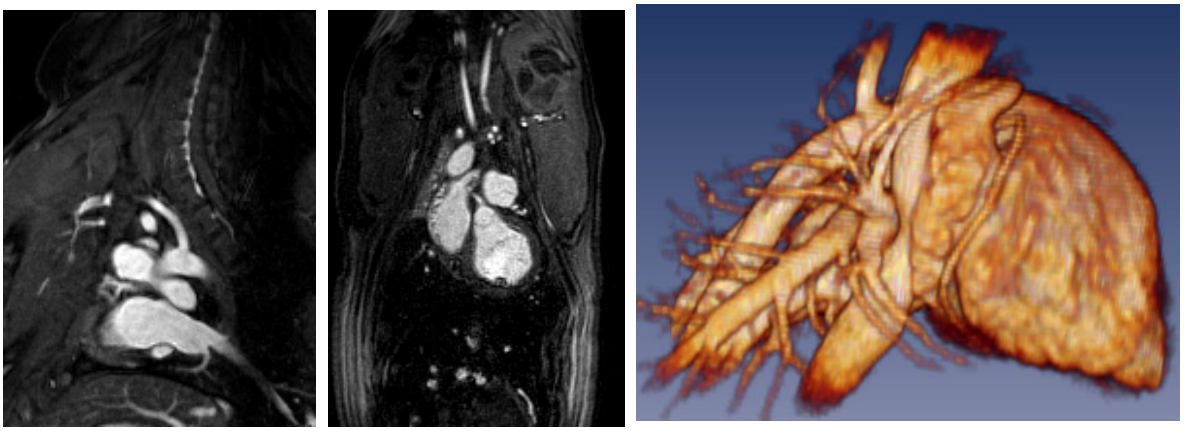

Fig. 1: FLASH and spiral original images; Volume rendering of one of 15 time steps (58 ms) showing the RCA in end diastole, acquired using 4D-FLASH.

References:

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3) Pilgrimm H.: PCT/DE 97/00578; 1997

4) Nguyen TD et al, Proc ISMRM 11, 728; 2003

5) Larson AC et al, Proc ISMRM 11, 379; 2003