Coronary MRI: Lessons from X-ray coronary angiography, the need for a T_2post pulse, and its implementation at 3T

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Introduction: Coronary MRI with high spatial resolution depends on segmented k-space data acquisition over many heartbeats. Studies investigated the best acquisition window position during low coronary velocity [1-3]. However, the precision of the beat-to-beat geometric coronary repositioning is crucial yet remains unknown. The aim of this study was therefore to measure the beat-to-beat repositioning uncertainty of coronary bifurcations on x-ray coronary angiograms. With these data, we tested the hypothesis that intervals with lower repositioning uncertainty of the coronary arteries exist within the cardiac cycle. Since we found that such a window of opportunity exists relatively early during systole, this has significant implications on sequence timing. In response, we have implemented early systolic coronary MRA with a T2post rather than a T2prep for contrast enhancement and have investigated its performance.

Methods: Routine diagnostic 2D cine breath-hold x-ray coronary angiograms of 10 patients (68 ± 7 years old) who underwent elective coronary angiography were acquired. The patients were not exposed to extra radiation and all study subjects provided informed consent. Images were acquired at 15 fps with a 0.322mm isotropic pixel size with synchronous ECG recording. From the middle section of the left coronary tree, 23 bifurcations were tracked independently by two investigators. Bifurcation coordinates throughout one cardiac cycle were compared with those from the subsequent cycles to quantify the repositioning uncertainty of the bifurcation for any given time delay after the R-wave of the ECG. Statistical analysis for the repositioning uncertainty of the coronary arteries was performed using a Student's t-test with false discovery rate (q=0.1) as correction for multiple comparisons leading to p<0.034 being statistically significant. When analyzing the repositioning uncertainty values, both a systolic and a mid-diastolic window of opportunity was identified (see Results below and Figure 1). Since in many cases mid-systolic imaging may be preferred over diastolic imaging [4], and since there is not sufficient time after the R-wave of the ECG to accommodate all the sequence elements necessary for coronary MRA, we developed a method that incorporates a T_2post pulse: a T_2prep module simply placed at the end of the RR interval to prepare the magnetization for the subsequent systolic acquisition, allowing early systolic imaging. This was combined with arrhythmia rejection to avoid adverse effects of RR irregularities. The methodology was applied to 14 healthy volunteers on a 3T MRI scanner (Siemens Trio, Erlangen, Germany). Free-breathing 3D segmented k-space gradient echo images (TE/TR=2.49/5.8ms, 1.2x0.9x2mm3 voxel size, field of view =320mm, matrix 253x300, 16 slices, α=16°, TE_{T2post}=60ms) with a diaphragmatic navigator for respiratory motion suppression and an acquisition window of 8 k-space profiles placed 150 ms after the R-wave were acquired. The T2post images were compared to those of a conventional diastolic T_2prep acquisition. Vessel sharpness, CNR and SNR were used to compare image quality.

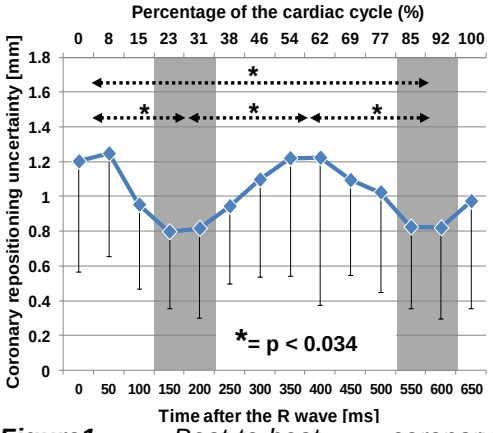

***Figure1**. Beat-to-beat coronary repositioning uncertainty with standard deviation bars. The two minima () statistically significantly lower than the rest of the cardiac cycle.*

Results: Beat-to-beat repositioning uncertainty of the coronary bifurcation measured on X-ray presents two statistically significant local minima (Figure 1) at mid-systole and mid-diastole, (0.8±0.5mm for both, p=NS). In Figure 2, representative examples of coronary MRA acquired in mid-systole with T2Post (left) and in mid-diastole using T2Prep (right) are displayed. The image acquired with T_2post shows a blood-myocardium CNR comparable to that from T_2prep. No significant difference in CNR between T2Prep and T2Post was observed (p=NS), but a higher overall SNR for myocardium and blood (both p<0.05), due to prolonged T_1 relaxation and blood inflow between the T_2post module and the data acquisition. Vessel sharpness in the T_2post was no different from that of the T_2prep (p=NS).

Discussion: Beat-to-beat repositioning uncertainty of the coronary arteries is surprisingly low (<1.2mm) at all times in the cardiac cycle. Windows of improved repositioning were identified in mid-systole and in mid-diastole and therefore, these two intervals may be the best candidates for coronary MRI data acquisition. Since diastole is more affected by heart rate variability than systole [3], we posit that mid-systolic imaging may improve image quality and diagnostic value of coronary MRI. However, systolic imaging cannot accommodate conventional magnetization preparation and motion suppression modules because of timing constraints. Therefore, a T_2post pulse was implemented as a logical next step. The results demonstrated that the T_2post is able to provide T_2 contrast also for systolic acquisition without loss in CNR, but with a significantly improved SNR when compared to the T_2prep.

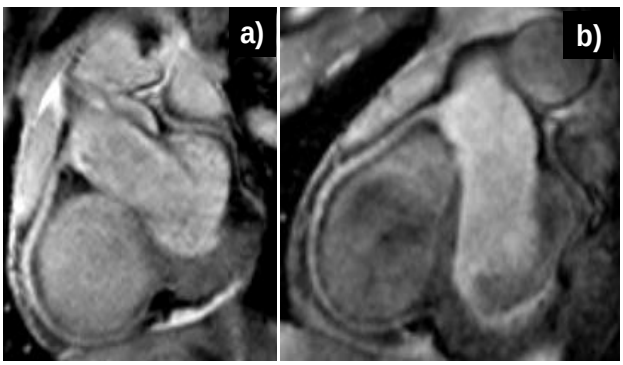

***Figure2**.Coronary MRA acquired in systole with T_2post (a), and in diastole with regular T_2prep (b).*

References: [1].Johnson et al,JCMR 2004,6:663 ; [2].Wang et al.Radiology 1999,213:751 ; [3].Gharib et al.JCMR 2007,26:921 ; [4]. Roes et al.JMRI 2008,27:1046.

1. My preferred presentation type is:

Oral

2. Keywords:

Coronary arteries, systolic imaging, T_2 prep

3. I am eligible for the Potchen Award

YES