Cross-sectional Dixon-Enhanced Spiral Cine Coronary Artery Magnetic Resonance Imaging at 3T

H. K. Agarwal[1], P. Koken[2], M. Schär[3], J. Yu[1], A. G. Hays[1], H. Eggers[2], R. G. Weiss[1], P. Börnert[2], and M. Stuber[4,5]
[1]Johns Hopkins University, Baltimore, MD, United States, [2]Philips Research Laboratories, Hamburg, Germany, [3]Philips Healthcare, Cleveland, OH, United States, [4]Department of Radiology, Centre Hospitalier Universitaire Vaudois and University of Lausanne, Lausanne, Switzerland, [5]Center for Biomedical Imaging (CIBM), Lausanne, Switzerland

INTRODUCTION: Cine cross-sectional area measurement of coronary arteries using diastolic 3T spiral MRI has shown great potential for the quantitative measurement of early atherosclerotic endothelial dysfunction [1]. This technique critically depends on the quality of fat suppression. For time-efficient cine image acquisition, slice selective spectral-spatial RF excitations have been combined with the spiral signal-readout [1]. However, B0 field inhomogeneity especially at high field strengths may lead to off-resonance artifacts and blurring which may adversely affect quantitative area measurements. For these reasons, we have used the 3-point-Dixon (3P-Dixon) technique which allows for reliable water/fat separation in the presence of B0 field inhomogeneity with the opportunity to estimate the latter [2]. Together with a sliding window conjugate phase reconstruction, this technique can be used to correct off resonance effects in the separated spiral images [3] for improved cross-sectional spiral coronary MRI.

METHODS: Cine cross-sectional spiral coronary MRI of the right coronary artery (RCA) of one volunteer was performed on a 3T clinical MR scanner (Achieva, Philips Healthcare, Best, NL). The protocol was approved by the Institutional Review Board of the hospital, and a written informed consent was obtained from the volunteer prior to the scan. The system was equipped with a 32-element cardiac phased array surface coil for signal reception and vector ECG technology [4]. Two cross-sectional slices perpendicular to the proximal RCA were acquired using a single-interleave cine spiral 2D imaging sequence (FOV=220mm; scan resolution =0.89x0.89mm^2; number of spirals=17; spiral acquisition window=14ms; α=20°; slice thickness=9mm) during a breath-hold. First, a spectral-spatial excitation was used to acquire 34 cine frames with a temporal resolution of 19.3ms as a baseline scan. Next, the 3P-Dixon technique was performed by acquiring three different echoes (TE increment=0.80ms) with a spatially selective excitation over three consecutive time frames in the cardiac cycle. The reduced temporal resolution with 3P-Dixon was compensated by the use of a sliding window reconstruction to maintain the number of cine frames (36 echoes obtained using 3-point Dixon with TR=18.8ms to generate 34 cine frames) per cardiac cycle. The reconstruction process consists of water/fat separation on the echo data using an algorithm similar to ref. [2] followed by a conjugate phase reconstruction (CPR) [5] for the field map-based de-blurring of the spiral images. The entire reconstruction process was directly integrated on the scanner and no off-line post processing was necessary.

RESULTS: Cine cross-sectional coronary MRI was successfully obtained with both the baseline and 3P-Dixon technique. The breath-hold duration was 18 heart beats. Figure 1 shows two time frames from the cine sequence acquired in mid-diastole (Td=646 ms) when the heart is almost stationary and, in early diastole (Td=461 ms) when the heart is rapidly moving. Since 3P-Dixon is affected by motion that may occur during three consecutive echoes, the coronary lumen is not well delineated in early diastole (solid red and blue arrows). However, in mid-diastole (solid yellow and pink arrows) a significant improvement is observed not only when compared to the early diastolic acquisition but also relative to the baseline scan. An increased amount of off-resonance blurring is observed in slice 2 when compared to slice 1 in the baseline images (dotted blue and pink arrows). 3P-Dixon with CPR clearly was able to remove this artifact, which leads to a better delineation of the coronary cross section with significantly improved visualization of other small anatomic structures such as the aortic valve (dotted white arrows). Furthermore, on all 3P-Dixon corrected images, an improved delineation of the ventricular septum is apparent with a visually improved signal-to-noise ratio of both the blood-pool and the myocardium.

DISCUSSION: We have successfully implemented the 3P-Dixon technique in conjunction with conjugate phase reconstruction for water fat separation and off-resonance artifact correction in cross-sectional cine spiral coronary MRI. The implementation was integrated on a commercial scanner requiring no off line processing, therefore improving the ease-of-use. While the proposed 3P-Dixon technique is less effective during periods of rapid coronary motion, the sliding window conjugate phase reconstruction ensures reconstruction of well-delineated coronary contours during periods of relative quiescence of the heart. This technique comes at no extra cost in scanning time and may critically support quantitative coronary endothelial function measurements. Further improvements will be necessary and include two-point Dixon or other data consistency enforcing approaches aimed at further reducing motion sensitivity.

ACKNOWLEDGEMENTS: This work was supported in part by the Reynolds foundation and NIH/NHLBI grants RO1HL084186 and ARRA 3R01Hl084186-04S1.

REFERENCES: [1] Hays AG, et al. JACC 2010;56:1657-1665. [2] Reeder SB, et al. MRM 2005;54:636-644. [3] Börnert P, et al. JMRI 2010;32:1262-7. [4] Fischer S et al., MRM'99;42:361-370. [5] Eggers H, et al. IEEE TMI 2007; 26:374-384.

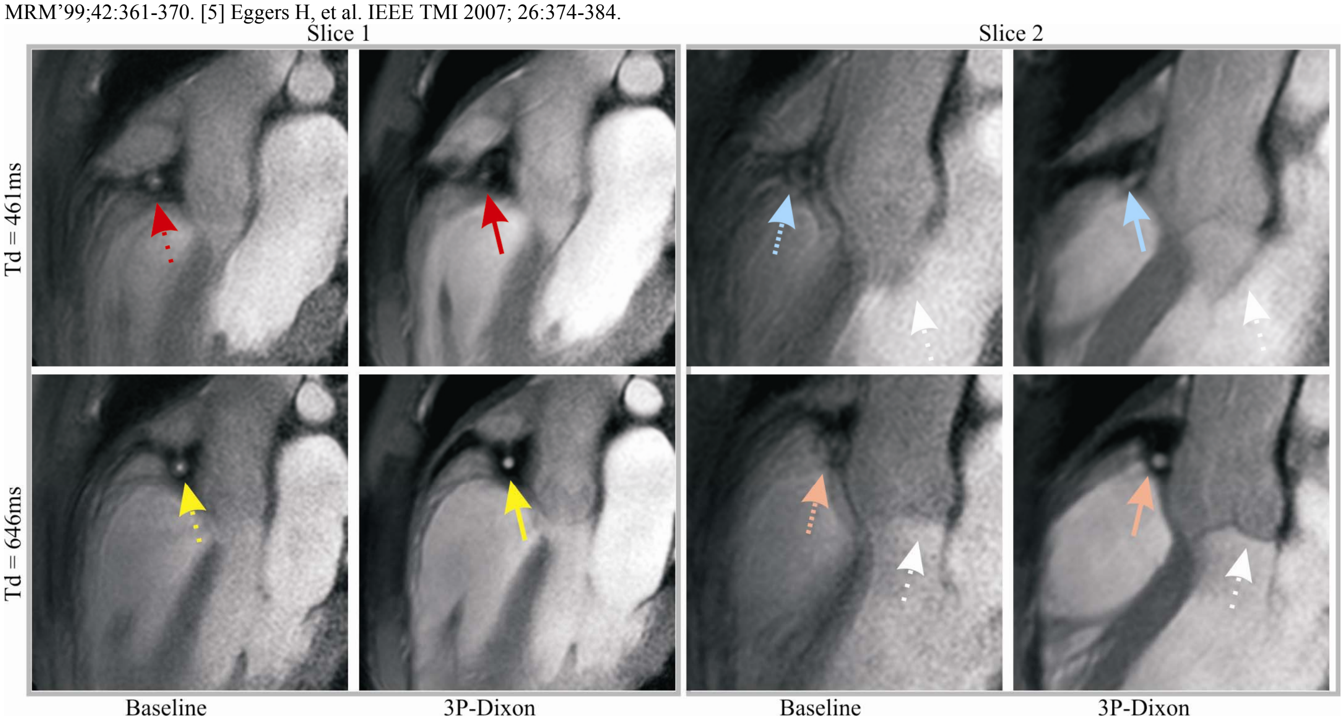

Figure 1: Two selected time frames (early diastolic: Td=461ms and mid-diastolic: Td=646ms) obtained using cine cross-sectional spiral coronary MRI of the right coronary artery from a healthy adult subject are shown for two different anatomical levels (Slice 1 and Slice 2). These acquisitions were repeated with a spectral spatial excitation (Baseline) and with the 3-point Dixon method that incorporates sliding window reconstruction.