# A Novel Slice-selective Implementation of the Adiabatic $T_2$Prep Sequence Objectively Improves Coronary Artery Conspicuity

Sahar Soleimanifard[1], Michael Schär[1,2], Allison G. Hays[1], Jerry L. Prince[1], Robert G. Weiss[1], and Matthias Stuber[1,3]

*[1]Johns Hopkins University, Baltimore, MD, United States, [2]Philips Healthcare, Cleveland, OH, United States, [3]University of Lausanne, Lausanne, Switzerland*

**INTRODUCTION:** In non-contrast coronary magnetic resonance angiography (MRA), the $T_2$ preparation pre-pulse ($T_2$Prep) [1] has been widely used for contrast enhancement between the coronary blood-pool and the myocardium [2-4]. To minimize flow sensitivity and the effect of field inhomogeneities, a non slice-selective version of the pre-pulse is commonly used. With the advent of high-field systems, an adiabatic version of this $T_2$Prep scheme was proposed [5] to avoid $B_0$- and $B_1$-related artifacts at 3.0T. However, independent of field strength, this non-selective pre-pulse affects the magnetization both inside and outside the imaged volume, resulting in a reduced steady-state magnetization of the in-flowing blood, and a resultant penalty in signal-to-noise-ratio (SNR). We hypothesize that a ***slice-selective*** $T_2$Prep would leave the magnetization of blood outside the imaged volume unaffected, and thereby minimize the penalty in SNR of the blood flowing into the coronary arteries. The purpose of this work was therefore to implement an artifact-free slice-selective $T_2$Prep sequence and to assess the gain in SNR and vessel conspicuity quantitatively.

**METHODS: Implementation:** The slice-selective $T_2$Prep was implemented by replacing the non-selective 90° RF pulses with slice-selective versions plus flow-compensating gradients using gradient moment-nulling, and an additional time gap between the $T_2$Prep and other pre-pulses ($T_{gap}$) to allow for inflow of a larger volume of blood with equilibrium magnetization (Fig. 1). On the scanner, the $T_2$Prep volume was graphically selected along the arterial axis and orthogonal to the imaged volume without covering the ventricles or the ascending aorta (Fig. 2C) to avoid saturation of the spins before in-flow into the coronary arteries. **Experiments:** Volume targeted three-dimensional navigator gated free-breathing coronary MRA [4] including a fast noise scan (~ 9sec) for SNR measurements on SENSE images [6] were acquired on a whole body 3.0T scanner (Achieva, Philips Healthcare, Best, The Netherlands) a) without $T_2$Prep, b) with the conventional $T_2$Prep, and c) with the proposed slice-selective $T_2$Prep in 10 healthy adult volunteers. Scan parameters were the following: TR = 4.1ms, TE = 1.5ms, FA = 20°, RF excitations per k-space segment = 25, SENSE factor = 2, FOV = 300×300×32mm$^3$, voxel size = 0.8×0.8×2.0mm$^3$, TE of $T_2$Prep = 50ms, $T_{gap}$ = 150ms, scan time ~ 2min (navigator efficiency ~ 40%). **Analysis:** On each coronary of interest, two endpoints were manually identified (yellow squares, Fig. 3C and 3D). Vessel centerline (dotted red line, Fig. 3C and 3D) and boundary (orange lines, Fig. 3C and 3D) were identified using an automatic algorithm developed in-house to minimize time and variability caused by manual interventions. Vessel boundaries, once segmented, were dilated by five pixels to identify the vessel-neighborhood region (blue lines, Fig. 3C and 3D). Three coronary artery segments were identified on each vessel according to the recommendations of American Heart Association [7]. Repeated measures of vessel boundary sharpness (VS), blood signal-to-noise-ratio (SNR), and vessel-neighborhood contrast-to-noise-ratio (CNR) were measured using anatomical and noise scans, and statistically compared using analysis of variance (ANOVA) with Tukey post hoc test.

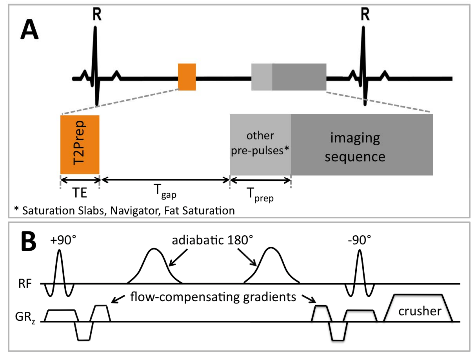


***Fig. 1.*** *(A) A time interval $T_{gap}$ added between $T_2$Prep and other pre-pulses allows for a larger volume of blood with equilibrium magnetization flowing into the imaged volume. (B) Schematic of the proposed slice-selective $T_2$Prep pulse sequence.*

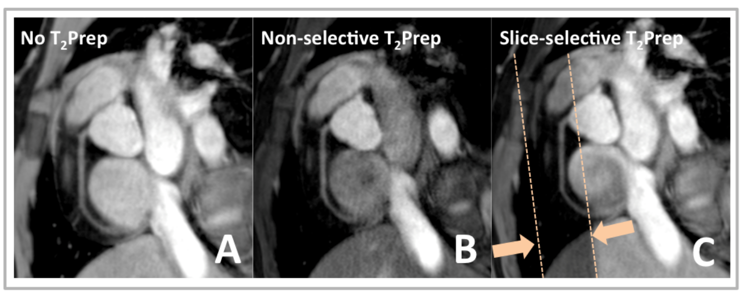


***Fig. 2.*** *Example of an RCA using no $T_2$Prep contrast (A), non-selective $T_2$Prep (B), slice-selective $T_2$Prep (C). Dotted lines illustrate the orientation of selective $T_2$Prep.*

**RESULTS:** Proximal and mid segments were identified on all images (n=10 for the right coronary artery (RCA); n=5 for the left anterior descending artery (LAD)). Distal segments were identified on 6 datasets only and thus excluded from analysis. Fig. 2C shows an RCA obtained with the slice-selective $T_2$Prep localized along the dark bar (arrows). VS improved significantly using the proposed implementation, when compared to the non-selective $T_2$Prep (proximal: 52±2% vs. 45±3%, p=0.0037; mid: 55±3% vs. 48±3%, p=0.0026, Fig. 4A). While both $T_2$Prep variants led to an SNR penalty when compared to no $T_2$Prep as previously reported [2], the slice-selective $T_2$Prep still led to a significantly improved SNR compared to conventional $T_2$Prep (proximal: 42.5±3.7 vs. 28.7±2.7, p<0.0001; mid: 33.1±3.5 vs. 25.0±3.3, p<0.0001, Fig. 4B). A similar finding was observed for CNR measurements (proximal: 18.8±2.5 vs. 13.0±2.4, p=0.0127, mid: 19.2±2.6 vs. 13.99±2.1, p=0.0036, Fig. 4C).

**CONCLUSION:** A slice-selective adiabatic $T_2$Prep significantly improves coronary artery conspicuity as compared to its conventional, non-slice selective counterpart.

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**REFERENCES:** [1] *MRM*'95; 33:689-96. [2] *Circulation*'99; 99:3139-48. [3] *NEJM*'01; 345:1863-69. [4] *JACC*'99; 34:524-31. [5] MRM'06 55:858-64; [6] JMRI'11; 33:1330-40. [7] Circulation'75; 51:5-40.

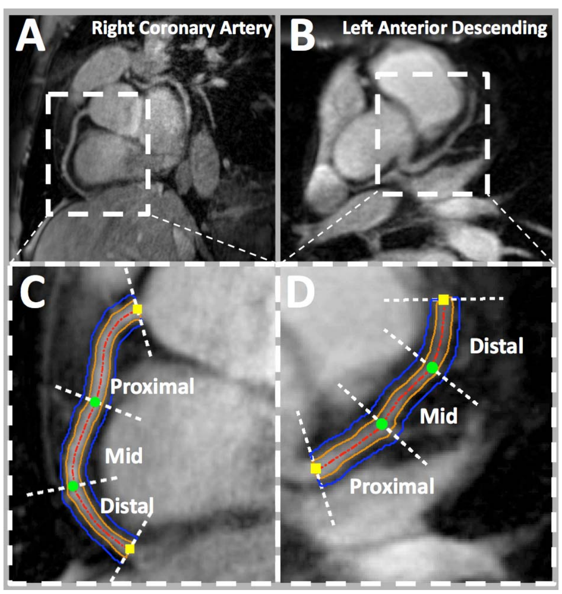


***Fig. 3.*** *Vessel centerline (dotted red line) and boundary segmentation (orange line) using two user-selected endpoints (yellow square). Blue lines mark vessel neighborhood.*

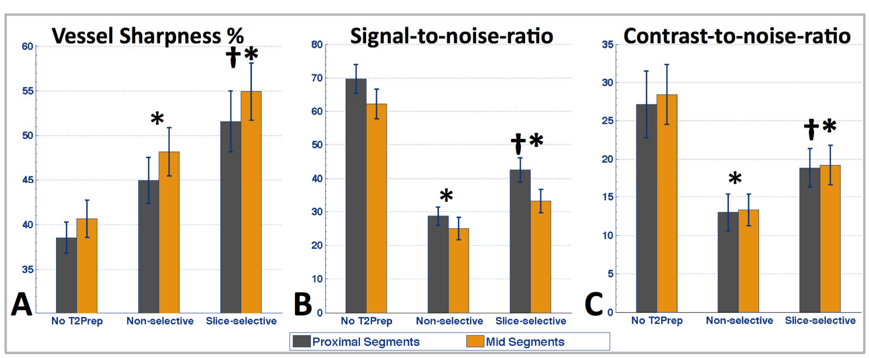


***Fig. 4***. *mean ± SEM. *p<0.05 vs. no $T_2$Prep; †p<0.05 vs. non-selective $T_2$Prep.*