Combined T_2-Preparation and 2D "Pencil Beam" Inner Volume Selection, Applied to Accelerated Reduced Field of View Coronary MRA

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Introduction: Two dimensional (2D) spatially selective radiofrequency (RF) pulses[1,2] may be used to constrain the location[3] from which an MR signal is obtained. This may lead to more time-efficient data collection by reducing the field of view (FoV) or may improve image quality by suppressing artefacts from outside the area of interest[4]. Meanwhile, T_2-Preparation[5], or T_2-Prep, is a magnetization preparation scheme used to improve blood/myocardium contrast. We propose incorporating a "pencil beam" 2D RF pulse into a T_2-Prep module, so as to produce a "2D T_2-Prep" that combines T_2-weighting with an intrinsic spatial selectivity. Numerical simulations, phantom validation, and *in vivo* results are presented.

Methods: The first RF pulse of a +90°,180°,180°,-90° adiabatic T_2-Prep[6] was replaced with a jinc-shaped RF pulse and spiral gradients (Fig. 1). This combination selectively excites a cylindrical volume[7]. Meanwhile, the final RF pulse (-90°) remains non-selective. As a result, the magnetization of the excited cylinder is restored, whereas magnetization outside of the cylinder is tipped into the transverse plane and spoiled. The RF excitation angles of the first and last pulse were also increased to ±100°, to further reduce signal via inversion recovery.

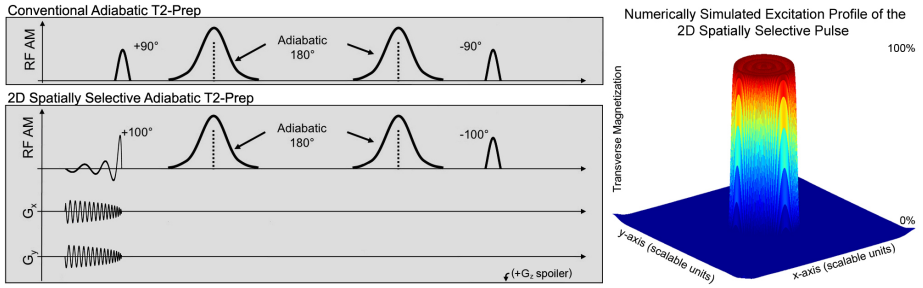

Figure 1: Schematic representation of the 2D T_2-Prep and the corresponding simulated excitation profile.

To predict the effect of this approach, the excitation profile of the 2D T_2-Prep pulse was simulated in MATLAB. After numerical simulations, the technique was implemented on a 1.5T clinical scanner (MAGNETOM Aera, Siemens AG, Healthcare Sector, Erlangen, Germany) and phantom images were acquired to compare the numerically predicted excitation profile to its experimental counterpart (Fig. 2). Next, volume targeted 3D images of the left coronary arterial system were acquired in 8 healthy adult subjects. All images were obtained using a 3D navigator- and cardiac-gated segmented k-space Cartesian gradient echo sequence, with FoV 432x262 mm, matrix size 432x262, 1.5 mm reconstructed slice thickness, 8 k-space lines/heartbeat, 40 ms T_2-Prep, water selective excitation pulses, RF excitation angle 20°, TE/TR/T_{acq}=5.18/11.62/92 ms. Full FoV images were acquired with both the conventional T_2-Prep and the 2D T_2-Prep. The 2D T_2-Prep scan was then repeated with a substantially reduced FoV (rFoV: 112x112 mm, matrix size 112x112) to accelerate scanning. All images were reformatted and analyzed using Soap-Bubble[8].

The 3 T_2-Prep techniques (conventional, 2D, and 2D with rFoV) were compared using vessel sharpness measurements, contrast-to-noise (CNR), and signal-to-noise (SNR) quantification in the blood and myocardium.

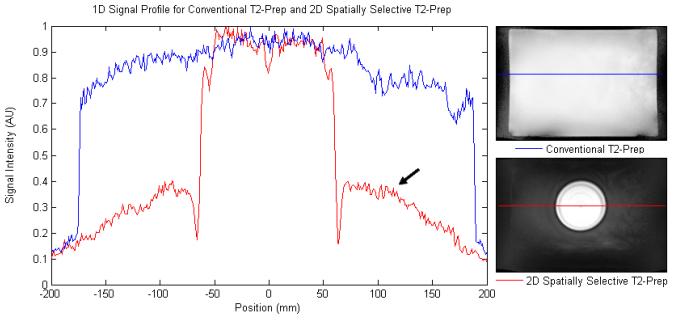

Figure 2: *In Vitro* Signal Profile for Conventional T_2-Prep vs 2D T_2-Prep

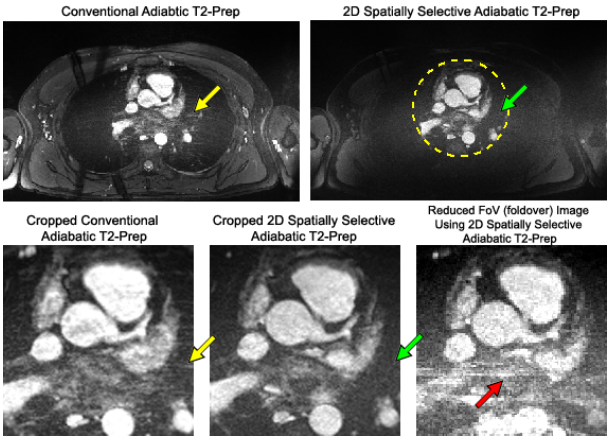

Figure 3: Comparison of T_2-Prep techniques *in vivo*

Results: The simulated excitation profile of the 2D pulse can be seen in Fig. 1, with corresponding, experimentally measured *in vitro* excitation profiles shown in Fig. 2. Note that a 100% background signal suppression is not obtained (black arrow). Sample *in vivo* images (prior to vessel-tracking image reformatting) are shown in Fig. 3, with corresponding measurements shown in Table 1. The region targeted by the 2D pulse is outlined by the dashed yellow circle. Note the respiratory artefacts originating from the chest wall on the conventional image (yellow arrow). These are significantly attenuated with the 2D T_2-Prep (green arrow). Additionally, the 2D T_2-Prep's mean blood and myocardium SNRs (349.0 and 108.3, respectively) stayed within the same range as the conventional T_2-Prep's (344.8 and 104.1). The 2D T_2-Prep also preserved blood-myocardium CNR (240.8) as compared to the conventional T_2-Prep (240.6), demonstrating that the 2D T_2-Prep successfully maintains T_2-weighting. Vessel sharpness was also comparable (50.8% conventional vs. 53.8% 2D T_2-Prep).

In going to a reduced FoV, the mean blood SNR (268.7) decreased significantly ($p<0.05$), as did the blood-myocardium CNR (166.5, $p<0.05$) and vessel sharpness (46.5%, $p<0.05$) as compared to the above sequences. However, these losses in SNR and CNR are consistent with the associated reduction in scan time, which results from the decreased number of phase encoding steps (262 vs. 112) in the rFoV image. As a result, total scan time was reduced by 60%. Myocardium SNR was not significantly affected, though artefactual contributions may have artificially inflated the rFoV numbers. For instance, residual foldover signal remains present in the rFoV image (red arrow), which is consistent with phantom measurements above.

Table 1: Mean SNR, CNR, and Vessel Sharpness (± SD) in Tissue ROIs for Select Imaging Strategies.

Image Property	Conventional T_2-Prep	2D Spatially Selective T_2-Prep	2D Spatially Selective T_2-Prep with rFoV
Blood SNR	344.8 ± 54.2	349.0 ± 58.8	268.6 ± 88.4 *,†
Myocardium SNR	104.1 ± 17.4	108.3 ± 26.9	102.1 ± 35.7
Blood-Myocardium CNR	240.6 ± 44.6	240.8 ± 41.5	166.5 ± 60.0 *,†
Vessel Sharpness (%)	50.8 ± 7.4	53.8 ± 3.9	46.5 ± 9.1 *,†

* Indicates a statistically significant diff. ($p<0.05$) between the conventional T_2-Prep and 2D rFoV T_2-Prep.
† Indicates a statistically significant diff. ($p<0.05$) between 2D T_2-Prep and 2D rFoV T_2-Prep.

Discussion: A 2D T_2-Prep shows promise to reduce respiratory motion artefacts and to potentially decrease scan time, while preserving the T_2-weighting of a conventional T_2-Prep. It should thus be considered as a tool to help accelerate T_2-prepared cardiac imaging.

Refs: **1.** Bottomley, JAP 62:4284 (1987) **2.** Pauly, JMR 81:43 (1989) **3.** Feinberg, Rad 156:743 (1985) **4.** Abd-Elmoniem, MRM 68:822 (2012) **5.** Britain, MRM 33: 689 (1995) **6.** Nezafat, MRM 61:1326 (2009) **7.** Nehrke, MRM 55:858 (1999) **8.** Etienne, MRM 48:658 (2002)