Multiple Preparation Magnetic Resonance Fingerprinting (MP-MRF): An Extended MRF Method for Multi-Parametric Quantification

Christian Anderson[1], Ying Gao[1], Chris Flask[1,2], and Lan Lu[2,3]

[1]*Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States,* [2]*Radiology, Case Western Reserve University, Cleveland, Ohio, United States,* [3]*Urology, Case Western Reserve University, Cleveland, Ohio, United States*

Target Audience: Researchers interested in quantitative MRI

Purpose: Magnetic resonance fingerprinting (MRF) offers rapid simultaneous multi-parametric quantification[1]. The initial implementation showed MRF's capability to generate maps of M0, T1, T2, and off resonance frequencies. This work has also demonstrated the potential to generate maps of other parameters, such as perfusion and diffusion. However, a more general MRF methodology to obtain a variety of imaging assessments has not yet been described. In this preliminary study, we have combined multiple conventional magnetization preparations with the MRF framework to obtain a "Multi-Preparation MRF" (MP-MRF) methodology that can be easily adapted to quantify many different MRI parameters. In this initial study, we describe how the MP-MRF framework can be used to assess diffusion and perfusion parameters and have demonstrated in simulation that MRF can provide simultaneous assessments of T1, T2, and velocity.

Methods: We incorporated conventional perfusion[2] and diffusion[3] preparation schema into the MRF acquisition designed with *a priori* variation in flip angle (0-70 degrees) and repetition time (12-25 ms). The MRF acquisition was simulated with a FISP imaging kernel to minimize artifacts. These magnetization preparations were applied periodically throughout the dynamic MRF acquisition to sustain contrast during the acquisition (brown arrows, **Fig. 1**). For the diffusion-MRF acquisition, we incorporated conventional diffusion preparation scheme by combining 90-180-(-90) degree radiofrequency (RF) pulses with diffusion gradient lobes. For the perfusion-MRF acquisition, we applied both slice-selective and non-selective inversions with an inversion time of 1400 ms to generate bright blood and dark blood contrast, respectively. Simulated diffusion and perfusion MRF profiles were generated to determine the effects of the respective preparations. The perfusion-MRF method was further examined on a digital Shepp-Logan phantom with different flow velocities in five local regions (2-18 mm/sec). Noise was added to simulated phantom (SNR~25). The precalculated perfusion MRF dictionary contained 33,594 profiles (T1 = 100-2000 ms, T2 = 40-500, velocity = 0-20 mm/sec).

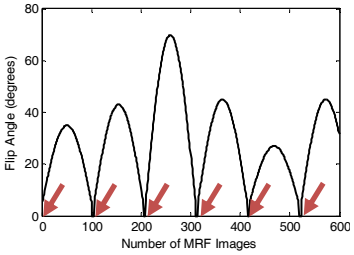

Figure 1. Flip angle schedule and with brown arrows at preparation locations.

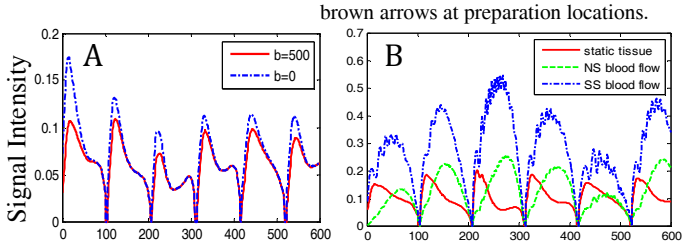

Figure 2. Preparation magnetization profiles. (A) Diffusion preparation with red (b=500) and blue (b=0) magnetizations. (B) Perfusion preparation showing profiles for non-selective (green) and slice selective (blue)

Results: Simulated signal evolution profiles for the diffusion-MRF and perfusion-MRF acquisition strategies are shown in **Figure 2**. Applying diffusion gradients (b=500 s/mm^2) resulted in a 20-50% reduction in signal intensity during the MRF profile in comparison to the MRF profile with no diffusion gradients (**Fig. 2A**). For the perfusion MRF simulation, flowing spins demonstrated altered profiles for the slice-selective and non-selective preparations as expected (**Fig. 2B**). Further, these profiles were also significantly different from the profiles for static spins. Perfusion MRF results of the simulated Shepp-Logan phantom are shown in **Figure 3** and demonstrate comparable results between theoretical and MRF estimates of T1, T2, and flow velocities.

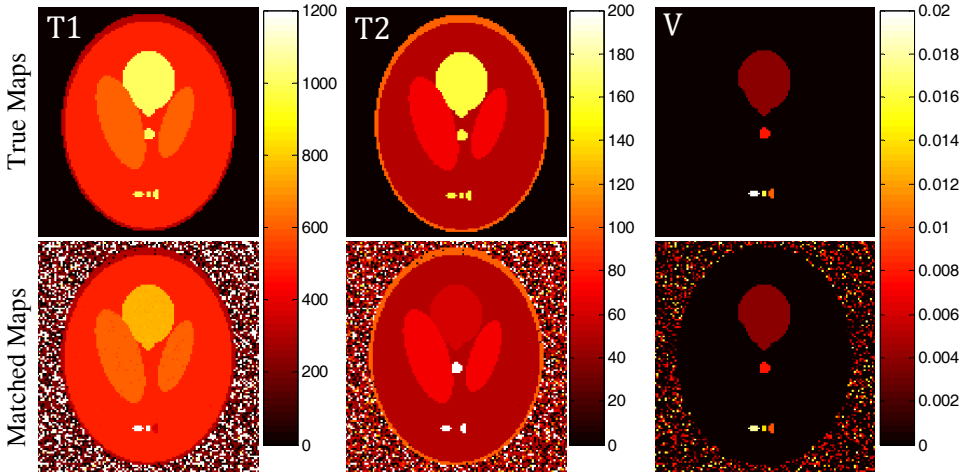

Figure 3. Digital phantom assessment of perfusion prepared MRF. Top row contains true maps of relevant parameters. Bottom row is maps after simulated acquisition. The first column is T1 mapping, second column is T2 mapping, and the third column is velocity mapping.

Discussion: In this study, we have developed an adaptable MP-MRF framework that combines multiple magnetization preparations with the dynamic MRF methodology to assess a variety of MRI parameters. In this initial development, we have simulated diffusion-MRF and perfusion-MRF acquisitions and demonstrated desired contrast in the respective signal evolution profiles. In addition, simulated Shepp-Logan phantom results suggested that the perfusion- MRF methodology is capable of generating simultaneous estimates flow velocity as well as T1 and T2 relaxation times. Overall, these results suggest that the MP-MRF methodology will provide a flexible platform that can be tailored for a wide variety of imaging applications.

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References: [1]Ma, D. *et al.* Nature, 2013. [2]Gao, Y. *et al.* NMR Biomed, 2014. [3]Lu, L. *et al.* MRM, 2012.