Feasibility of Diffusion Tensor Imaging with Magnetic Resonance Fingerprinting

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Target Audience: Diffusion MRI researchers.

Purpose: To determine the feasibility of magnetic resonance fingerprinting (MRF) for diffusion MRI. The MRF framework[1] has a number of attractive features for quantitative imaging such as speed, precision and robustness against artifact. We examine, by simulation, the potential of MRF for diffusion MRI.

Methods: Fig. 1 shows the building block for the pulse sequence. An RF pulse with flip angle, α, is followed by a symmetric bipolar diffusion gradient, $\vec{G}$, an RF pulse of opposite polarity and another bipolar diffusion gradient, $\overrightarrow{G'}$. The directions and amplitudes of the diffusion gradients are chosen from a pseudorandom distribution with a zero-mean normal distribution and magnitude ranging from 0 to 40mT/m. Timing parameters are fixed (RF pulse separation 30 msec, gradient duration 10 msec, magnetization readout 26 msec after the RF pulse, 500 pulses) as is the flip angle (60°). Response of signal corresponding to diffusion tensors with three different orientations (axial direction at 0°, 45° and 90° from the z-axis) and the same eigenvalues [(0.35 , 0.35, 1.4)x$10^{-3}$$mm^2$/sec] was simulated using the formalism of Stejskal[2] in Matlab (the Mathworks).

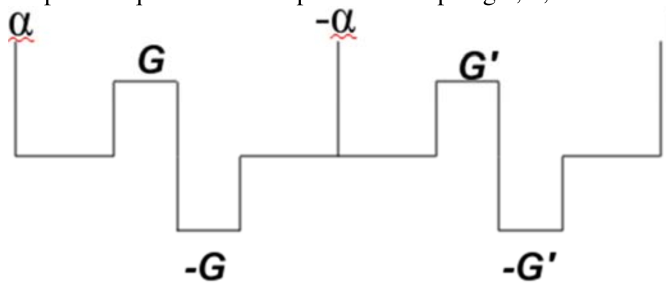

Fig. 1 Sketch of basic element of MRF-diffusion MRI pulse sequence

Results: Fig. 2a shows the time course of magnetization in response to the pulse sequence for a diffusion tensor with axial direction along the z-axis. Fig. 2b compares time courses of responses at the first for the first 50 time pulses of diffusion tensors with axial direction at 0° (blue), 45° (green) and 90° (red) with respect to the z-axis.

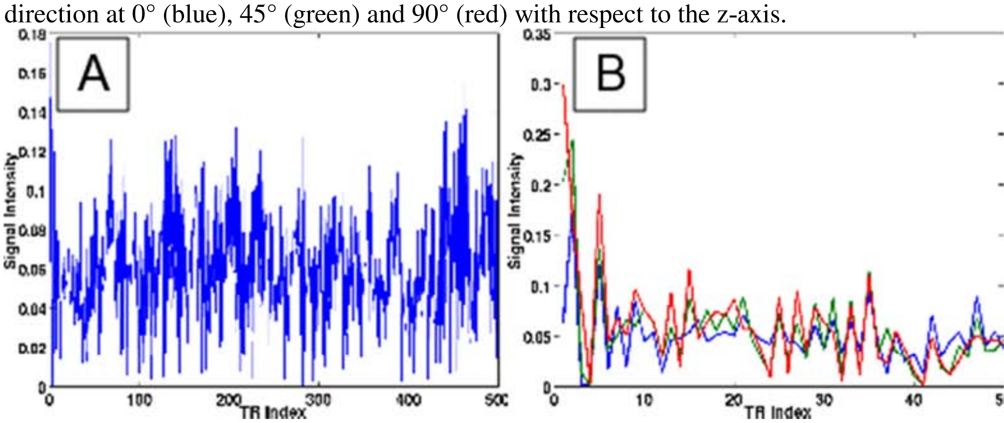

Fig 2 Signal evolution of Magnetization (A) and differences in responses of differently-oriented diffusion tensors (B)

Discussion: The design of the pulse sequence, with paired equal and opposite RF pulses and bipolar gradients was needed to render the signal large enough to be measurable. As shown in fig. 2a, the overall magnitude of the signal is large enough to be measured with conventional MR equipment. Fig. 2b demonstrates another feature necessary for the MRF framework to succeed: separation of signal responses for different parameterizations. The pulse parameters were chosen to accentuate the difference between these signal responses. Future work will focus on optimization of parameters, computationally efficient dictionary searches for fitting acquired data as well as experimental tests. The utility of the framework for more complex models, including fiber crossings and q-space acquisitions will also need further examination.

Conclusion: The results provide a proof-of-principle of application of the MRF framework to diffusion MRI. With further optimization, it may be possible to address a number of fundamental problems with diffusion MRI such as long scan times and low signal-to-noise ratio.

References

1. Ma D, Gulani V, Seiberlich N, et al. Magnetic resonance fingerprinting. Nature.495(7440):187-92.
2. Stejskal EO. Use of Spin Echoes in a Pulsed Magnetic-Field Gradient to Study Anisotropic Restricted Diffusion and Flow. Journal of Chemical Physics. 1965;43(10):3597-603.