MR Fingerprinting Using Spiral QUEST

Yun Jiang[1], Dan Ma[1], Renate Jerecic[2], Vikas Gulani[1,3], Nicole Seiberlich[1], Jeffrey Durek[3,4], and Mark A. Griswold[1,3]

[1]*Department of Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States,* [2]*Siemens AG,Healthcare Sector, Erlangen, Germany,* [3]*Department of Radiology, Case Western Reserve University, Cleveland, Ohio, United States,* [4]*Case School of Engineering, Case Western Reserve University, Cleveland, Ohio, United States*

Target audience: For those who are interested in novel pulse sequence design and quantitative imaging.

Purpose: MR Fingerprinting (MRF)[1] is a novel concept to simultaneously generate quantitative maps by matching acquired spatially and temporally incoherent signals to a pre-calculated dictionary. Instead of assuming a constant signal as in conventional MRI, MRF fully embraces the signal dynamics by varying acquisition parameters, such as flip angle and repetition time, to generate unique signal evolution for each tissue type. Previously a TrueFISP based MRF sequence has been used to demonstrate this concept. Multiple parametric maps, such as T_1, T_2, proton density and field map, can be calculated. In this study we explore the potential of MRF by using QUEST - QUick Echo Split imaging Technique[2,3] as a building block for MRF sequences.

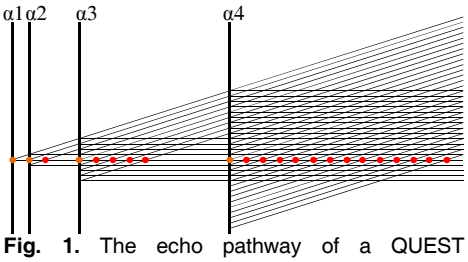

Fig. 1. The echo pathway of a QUEST sequence with 4 RF pulses. The red dot represents spin echo, and the orange dot represent RF echo.

Methods: Conventional MRI sequences typically use a single repetition time and a fixed set of flip angles to generate signal. Higher echo pathways are either refocused or spoiled to help the signal reach steady state. The key of an MRF sequence is to generate a unique signal evolution using a combination of different acquisition parameters. QUEST is a sequence which can be used to achieve the maximum number of echoes when utilizing a small number of RF pulses. Each echo pathway is separated by increasing the delay between the RF pulses according to $\tau_n = 3^{n-1}\tau_0$, where τ_0 denotes the minimal duration between the RF pulses. Fig. 1 shows the echo pathway of a QUEST sequence with 4 RF pulses. Up to 18 spin echoes and 4 RF echoes (FIDs) are generated with 4 RF pulses. Each of these echoes has a different T_1 and T_2 weighting, which is ideal for MRF to generate unique signal evolutions. In this initial study, each echo pathway was acquired using a variable-density spiral trajectory[4]. We repeated this 4 RF pulse QUEST block for 15 times. For each repetition, we randomly varied the minimal RF duration τ_0 (10-13 ms) and flip angles (0-60 degrees), generating a highly variable signal. The total acquisition time was around 5 minutes for fully sampled 48-shot spiral acquisition. To validate this method, a study was performed with phantoms with a wide range of T_1 (60-1800 ms) and T_2 (30-200 ms) values. The experiment was performed on a Siemens MAGNETOM Espree 1.5T (Siemens AG, Healthcare Sector, Erlangen, Germany). A dictionary of the signal evolutions with a range of T_1 (50-2000 ms) and T_2 (10-300 ms) values was created using a Bloch simulation. Generally, any pattern recognition algorithm can be used to select the element from the dictionary that best represents the acquired signal in MRF. Here we used Orthogonal Matching Pursuit (OMP)[5] to calculate the corresponding T_1, T_2, proton density. To evaluate the QUEST MRF performance, a saturation recovery spin-echo (13 TRs ranging from 50 ms to 5000 ms with TE of 8.5 ms) and fast spin echo (15 echoes with TEs from 15 ms to 225 ms with TR of 10 seconds) sequences were performed to quantify T_1 and T_2 values in phantom, respectively. T_1 and T_2 values were calculated by a pixel-by-pixel three-parameter nonlinear least squares fitting.

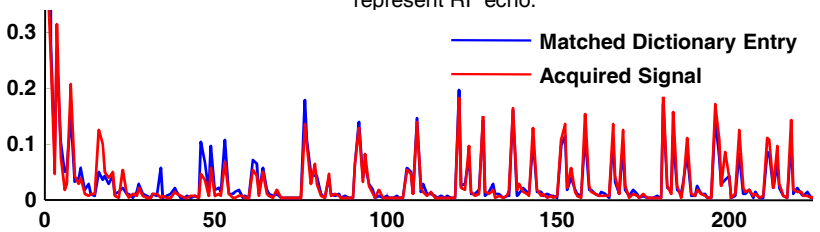

Fig. 2. An example of signal evolution from the acquired signal (red) and matched dictionary entry of MRF (blue).

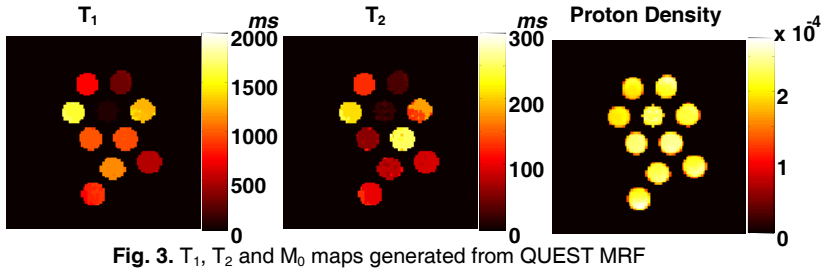

Fig. 3. T_1, T_2 and M_0 maps generated from QUEST MRF

Results and Discussion: Fig. 2. shows the signal time course from one pixel of acquired signal and its matched dictionary entry. Fig. 3 shows reconstructed T_1, T_2 and M_0 maps from QUEST MRF. Fig. 4 shows the comparison of T_1 and T_2 values obtained from QUEST MRF and spin-echo methods. It shows that T_1 and T_2 values are in good agreement with the traditional methods. The ability of QUEST to separate each echo pathway helps generate specific MRF signatures for the relaxation parameters. When using the minimum number of RF pulses to generate the maximum number of echoes, it also reduces SAR dramatically, which should promote the application of MRF at 7T and above. It may also help to extend the quantification to other parameters, such as perfusion and diffusion, etc. Thus we believe that QUEST provides another unique tool to explore MRF sequence design.

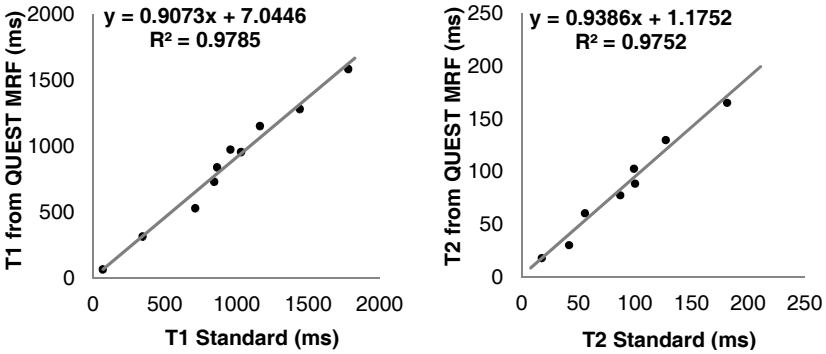

Fig. 4. The comparison of T_1 (right) and T_2 (left) values obtained from QUEST MRF and standard spin-echo methods.

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References: [1]Ma D, et al. ISMRM 2012 p.288. [2] Heid O, et al. *Magn Reson Med* 1993; 29:280-283. [3]Jerečić R, et al *Magn Reson Imaging* 2000;18:23-32. [4]Hargreaves BA. http://mrsrl.stranford.edu/~brian/vdspiral [5]Tropp J el al. *IEEE Trans Inf Theory* 2007; 53:4655-4666.