Robust Fast Clinical Neurological Examination using Golden Angle Ordered Radial IR-TrueFISP

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Introduction: A typical clinical neurological MRI examination includes the acquisition of images with several different contrast weightings, such as T_1-weighting, T_2-weighting, and fluid attenuation via inversion recovery (FLAIR). Generation of each type of contrast requires a separate acquisition, each of which contributes to a total scan time of several minutes in length. Ideally, comparable slices for each contrast would be perfectly registered with each other, but in practice this ideal is precluded by inter-scan motion. Here, we present a radial steady state method to acquire estimates of tissue relaxation parameters and proton density that permits estimation of "synthetic" MR images with multiple contrast weightings in a very short scan time.

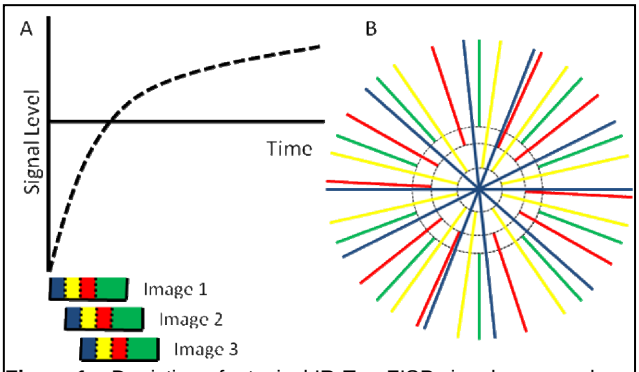

Figure 1 – Depiction of a typical IR-TrueFISP signal curve and sliding window over a period of ~5 s (a) and golden angle echo sharing scheme (b). In this example, the central region (blue) contains 5 projections, then 5 more are included in the next 2 rings (yellow then red), and all are included in the outer region.

Theory: Previous work has demonstrated that a segmented rectilinear inversion-recovery prepared TrueFISP acquisition can be used to estimate T_1, T_2, and M_0 by sampling the signal recovery after inversion [1]. A series of images were reconstructed at various times after inversion, and the signal time course for each pixel was fit to a model including the 3 tissue parameters. Several repetitions, and hence increased scan times, were required in order to acquire enough data to yield an acceptable fit (T_A=2:08), resulting in still unacceptably long scan times. Because radial acquisitions acquire low spatial frequency (ie contrast-bearing) portions of k-space during each TR, a sliding window echo sharing reconstruction [2,3] as shown in Figure 1 can be applied to the previous IR-TrueFISP acquisition and reconstruct the time course after a single inversion. In this manner, appropriate temporal resolution can be achieved to avoid motion induced mis-registration. Golden angle ($\Theta(n)=n*111.2461°$) projection ordering allows flexibility in the reconstruction, in that the number of projections contributing to the contrast of each image is not fixed during the acquisition but can be determined retrospectively.

Methods: A radial TrueFISP pulse sequence was implemented using a slice selective adiabatic inversion pulse, α/2 preparation, and golden angle projection ordering. Experiments were performed on a 1.5T Siemens Espree system (Siemens Medical Solutions, Erlangen, Germany), and written informed consent was obtained in compliance with our institution's IRB. Offline image reconstruction and parameter fitting was performed using Matlab (The Mathworks, Natick, MA). Asymptomatic volunteers (6) and one patient were imaged using this technique. For a typical head examination the following parameters were used: TR/TE/α=4.46 ms/2.23 ms/45°, 1023 projections, resulting in an acquisition time of 4.56 s per slice, 54.7s for 12 slices. Parameter maps were estimated in Matlab using a nonlinear least squares fitting algorithm across the time series of IR-TRUFI images. Using fitted parameter maps, perfectly registered images can be synthesized for any arbitrary contrast after the acquisition. The example shown here was reconstructed using 31 projections in the center of k-space, an additional 31 projections in each of the next 2 rings, and a total of 279 projections in the outer regions of k-space. Standard clinical T_1w SE (TR/TE = 552 ms/15 ms, T_A=2:24, 12 slices), T_2w TSE (TR/TE/α = 4000 ms/88 ms/150°, T_A=1:42, 12 slices), and FLAIR TSE (TR/TE/α/TI = 9000 ms/111 ms/150°/2500 ms, NS=2, T_A=2:08, 12 slices) images were also acquired at the same slice positions as the synthetic images for the purpose of comparison.

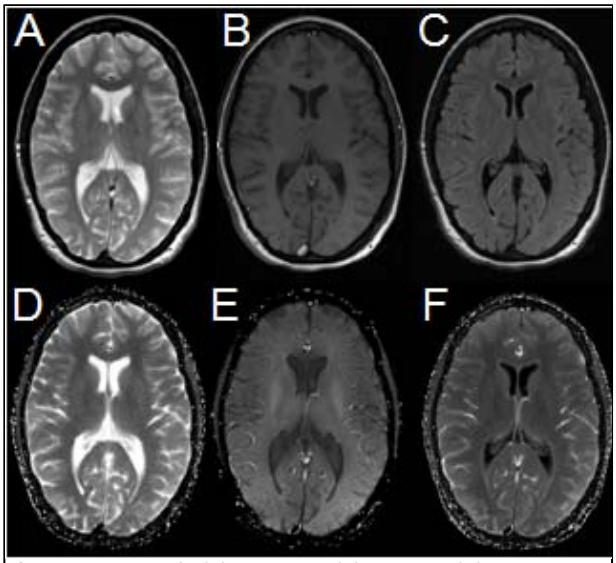

Figure 2 – Example (A) T2w TSE, (B) T1w SE, (C) FLAIR TSE, (D) synthetic T2w TSE, (E) synthetic T1w SE, and (F) synthetic FLAIR TSE.

Results and Discussion: T_1w SE, T_2w TSE, and FLAIR TSE images from a standard clinical protocol are shown in Figure 2 along with synthetic images calculated from the fitted T_1, T_2, and M_0 maps. The technique presented here provides accurate synthetic estimates of T1, T2 and FLAIR acquisitions from the same golden angle echo sharing radial scan in a scan time 6.8 times faster (54.7s) than a clinical standard method (6:14). Acquisition of a single IR-TRUFI dataset over 4.56 s, repeated for each slice, requires patients remaining stationary for 54.7 seconds versus over 6 minutes in conventional acquisition. Although this technique can theoretically reproduce any acquisition which can be represented in analytical form requiring only T_1, T_2, and M_0, it should be noted that some qualities of the clinical sequences cannot be preserved, such as the well known TSE bright fat property. Additionally, the bright blood property of the underlying TrueFISP acquisition does affect image contrast in perfused tissues. This technique has the potential to dramatically decrease examination time per patient, thereby increasing patient comfort and compliance, decreasing inter-scan motion, and increasing patient throughput.

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References: [1] Schmitt P et al., MRM 51:661–667 (2004) [2] Gulani V et al., RSNA 2004:398 (2004) [3] Song H et al., 44:825–832 (2000)