On the feasibility of hybrid acquisition in SPACE

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Introduction: A variant of the 3D turbo spin echo sequence with variable refocusing flip angles (aka SPACE) employs non-selective refocusing RF pulses to achieve short echo spacings during imaging with long echo trains. However, the use of non-selective RF pulses results in a single slab acquisition in SPACE imaging. In typical SPACE protocols, the duration of the echo train is only about 20% of the TR, which means that 80% of the time is purely spent waiting for signal recovery. In common 2D sequences, such inefficiency can be avoided by interleaved multi-slice excitation. Unfortunately this acquisition strategy is not applicable to the SPACE sequence. In order to improve the time utilization ratio, in this work, we investigate the feasibility of acquiring a second contrast in the waiting time of TR in single slab SPACE imaging. Preliminary results of such a hybrid SPACE prototype are presented.

Method: In the presented hybrid sequence, a second echo train is inserted into the waiting time of each TR to acquire another contrast. To maintain the quality of SPACE imaging, the second echo train needs to be restricted to either one of the two types: 1) It affects the SPACE image, but only within an acceptable level; or 2) It has no influence on the SPACE image. *Type 1*: An instance of this type is an echo train with small flip angles, which typically acquires gradient echo (GRE) images. To quantify the influence of the GRE train on the SPACE imaging, the extended phase graph (EPG) algorithm[1] was employed to simulate the hybrid sequence (Fig1). The parameters used in the simulation: TR = 3000ms; flip angle scheme in SPACE echo train (length = 120) optimized for T2 weighted contrast; waiting time ~= 2500ms; ESP_g = 10ms; FA_g varies from 5 to 20 degree; ETL_g varies from 20 to 160; $RT_b = RT_a$; gray matter T1/T2 = 1200ms/90ms; CSF T1/T2 = 3000/1000ms. After fixing FA_g (= 10 degree) and ETL_g (= 40), different ESP_g were also simulated. The hybrid acquisition of the T2w SPACE image and the GRE based susceptibility weight image (SWI)[2] was implemented and tested on a 3.0T clinical MR scanner (MAGNETOM Trio, Siemens, Erlangen, Germany) with the above parameters for SPACE and the following parameters for SWI: FA_g= 15 degree; ESP_g= 28ms; TE_g = 20ms; ETL_g = 60. *Type 2*: An instance of the second type is the application of different chemically selective excitations in the SPACE echo train and the second echo train, for example water imaging in the SPACE echo train and fat imaging in the second echo train. The combination of SPAIR fat suppression[3] in SPACE imaging and the water excitation in GRE imaging was implemented and tested on a 1.5T clinical MR scanner (MAGNETOM Espree, Siemens, Erlangen, Germany) with the following parameters: TR = 1500ms; TE_{space} = 40ms; ETL_{space} = 40; FA_g= 18 degree; ESP_g= 18ms; TE_g = 8ms; ETL_g = 38. For all in vivo experiments, *k*-space was randomly sampled and compressed sensing reconstruction was performed. Both contrasts used independent view ordering schemes. In the second contrast, pseudo radial reordering in ky-kz plane was implemented with the acquired echoes ordered from periphery of *k*-space towards the center in each TR.

Results & Discussion: Fig2 shows that for Type 1 to avoid a general degradation of the SPACE image it is necessary to limit the flip angle and echo train length in the second contrast based on the tissue with the longest T2 relaxation time. To limit the SPACE signal attenuation < 20%, a typical configuration is: $ETL_g \leq 30/1000$ms waiting time with $FA_g \leq 10$ degree in brain scan. Fig3 shows that the variation of the echo spacing in the second contrast doesn't affect the SPACE signal. This allows one to use low readout bandwidth to improve the SNR in the second contrast, without causing further degradation in the SPACE image. In addition, long TEs can also be achieved to obtain susceptibility weighting in the second contrast. In Fig4, a hybrid acquisition of SPACE and SWI images of a volunteer shows the feasibility of the method. Fig5 demonstrates a hybrid acquisition of proton density weighted SPACE imaging with a SPAIR fat suppression and fat excited GRE imaging using binomial composite pulses. In contrast to DIXON based water/fat separation[4], this hybrid acquisition doesn't prolong the total acquisition time and the echo spacing, and at the same time it maintains the quality of original SPACE image.

Conclusion: We proposed two types of hybrid acquisitions for the SPACE to improve its time utilization ratio. Encouraging results from in vivo experiments show the feasibility of the approach.

References: 1. Weigel M, J Magn Reson 2010; 205:276-285; 2. Haacke EM, MRM 2004 Sep; 52(3):612-8; 3. Udayasankar, U. K. J. Magn. Reson. Imaging, 28: 1133–1140; 4. Madhuranthakam, A. J. J. Magn. Reson. Imaging, 32: 745–751 (2010).

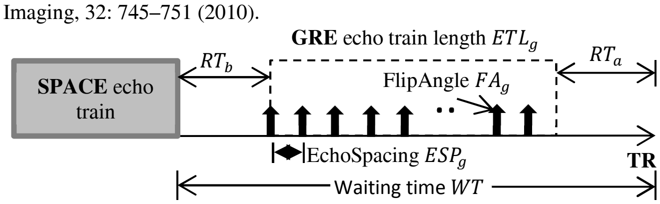

Fig1. Diagram of the SPACE-GRE hybrid sequence

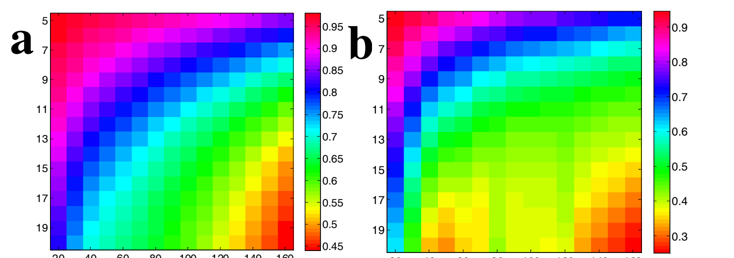

Fig2. Relative signal attenuation in the SPACE image caused by the second echo train: **a**) gray matter; **b**) CSF. The horizontal axis is L_g; the vertical axis is FA_g in degree.

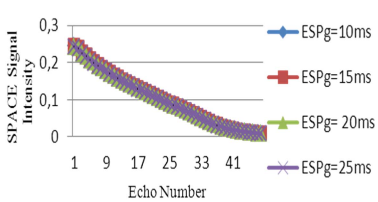

Fig3. The influence of different echo spacing in GRE echo train on the signal intensity in the SPACE echo train.

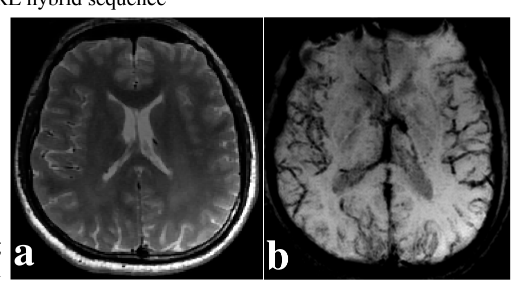

Fig4. Hybrid acquisition of (**a**) a T2 weighted SPACE image and (**b**) a SWI image.

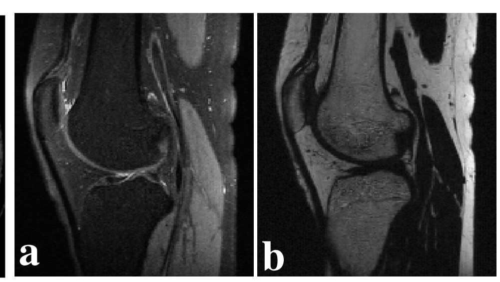

Fig5. Hybrid acquisition of (**a**) a SPACE image with SPAIR fat suppression and (**b**) a GRE image with fat excitation using binomial composite pulses.