SAR and Scan-Time Optimized 3D Whole-Brain Double Inversion Recovery (DIR) Imaging

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Target Audience:

Neuroscientists and clinicians who use the DIR sequence for gray matter imaging and lesion detection.

Purpose:

The aim of this project was to develop a double inversion recovery (DIR) Turbo-Spin-Echo (TSE) sequence enabling whole brain coverage (resolution <= 1mm^3) in short scan times (< 10 min). Using a standard DIR sequence [1], this goal is difficult to achieve, even at moderate field strength (1.5T) and especially at higher field (7T). This is due to SAR limitations, as well as T_2 induced image blurring, since long echo train acquisitions would be necessary to reach the desired scan times. To overcome these limitations a 3D-DIR-TSE sequence dedicated for high field applications was developed. Initial results are shown for 1.5T. A high field implementation is planned for the future.

Methods:

All imaging experiments were performed on a MAGNETOM Avanto 1.5T (Siemens AG, Healthcare Sector, Erlangen, Germany) using a 12 channel head coil. A 3D non-selective variable flip angle (vFA) DIR-TSE sequence was developed to acquire predefined signal shapes along the echo trains. Calculation of the vFA trains was based on the extended phase graph algorithm [2]. The target signals were chosen to follow an exponential decay with an initial plateau (see Figure 1), and were optimized to yield highest possible SNR while maintaining the predefined signal shapes. This was achieved by applying a bisectioning algorithm to the vFA calculation. The starting flip angle of the train was iteratively optimized until the maximum possible signal intensity was reached. The decay rates of the exponential envelopes were chosen as small as possible to guarantee a flat modulation transfer function (MTF) in k-space, thus resulting in a narrow point spread function (PSF) in the image domain.

Additionally, an optimized DIR preparation module was implemented, employing hypersecant (HSN) inversion pulses with exponents N>1 to further reduce SAR and/or improve inversion efficiency [4]. The inversion times were adjusted to suppress CSF and white matter simultaneously.

For scan time reduction, optimized linear (for T2 weighting), as well as spiral center out (for PD weighting) reordering schemes were implemented [3]. Both reordering schemes allow elliptical scanning, partial Fourier acquisition, and parallel imaging (Figure 2).

Imaging was performed in a healthy volunteer using the following parameters: TI1/TI2/TR = 2364/356/4000 ms, ETL = 64, 1x1x1 mm^3 resolution, matrix size 256x240x160 (whole brain coverage), 2D-Grappa factor 4 (2x2). Total scan time: 9:30 min.

Results:

Figure 3 shows a representative axial slice of a DIR acquisition in a healthy volunteer. Signal from white matter and CSF was completely suppressed. The PD weighted acquisition resulted in increased SNR compared to the T2-weighted approach. However, due to the spiral center out reordering blurring is slightly more pronounced.

Conclusion:

It was shown that high resolution, 3D whole brain DIR imaging in less than 10 min scan time is possible at 1.5T. This was achieved by increasing the ETL compared to standard TSE sequences and reducing the total number of echo trains. A 7T implementation is planned for the future. For high field applications, optimization of image contrast could be achieved by substitution of the DIR module by a magnetization prepared (MP)-DIR module such as proposed by Visser et al. [5].

References:

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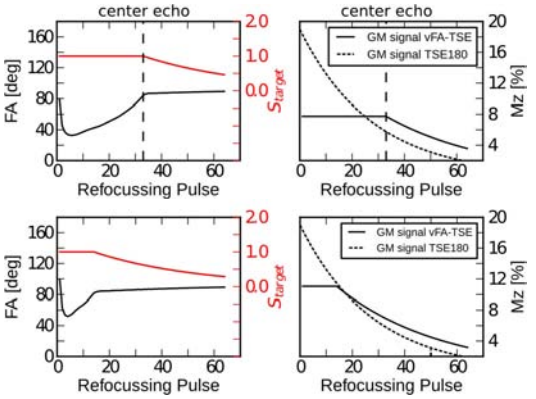

***Figure 1: Left*: Calculated flip angle trains to yield the desired signal shapes for gray matter (depicted in red). *Right*: Simulated DIR signal for vFA-TSE and TSE180 for comparison. The top row shows a train and target signal for linear (T_2w) and the bottom row for spiral center out (PDw) reordering.**

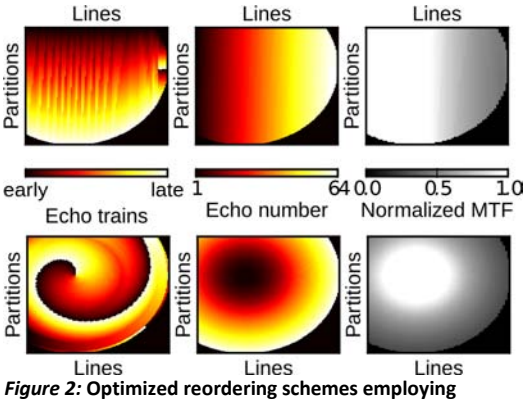

***Figure 2:* Optimized reordering schemes employing elliptical scanning and partial Fourier acquisition. *Top*: Linear reordering. Bottom: Spiral reordering. *Left*: Time point of echo train acquisition *Middle*: Reordering of the corresponding echoes of each train into k_y-k_z –space. *Right* : Resulting magnetization transfer function (MTF)**

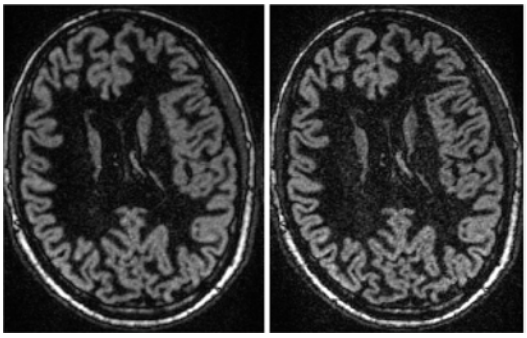

Figure 3 : Axial DIR images of a healthy volunteer. Left: PD-weighted. Right: T_2-weighted