Background suppressed 3D Perfusion Measurement using Arterial Spin Labeling and single-shot 3D-GRASE

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Introduction:

Arterial spin labeling (ASL) produces perfusion-weighted images without the use of contrast agents by acquiring two data sets with different preparations. Typically, the signal difference between these two data sets is very small (on the order of 1%). Therefore, the scanner hardware is adjusted optimally only for each single data set, i.e. the stationary tissue, but not for the labeled blood reducing the available dynamic range of the perfusion-weighted data. Since the signal of the stationary tissue is not needed for the perfusion measurement it can be reduced by proper use of additional rf-pulses.

Background suppression (BS) techniques usually combine multiple inversion pulses [1] to null the magnetization of signal components with different T1 relaxation times. Unfortunately, the resulting signal equations, which have to be solved to calculate the timing of the rf-pulses are rather complex and can be solved only numerically for arbitrary T1 combinations. However, an analytical solution is possible under certain assumptions and we solved the equation system for two inversion pulses and certain T1 combinations. We combined this background suppression for arbitrary inflow times with a new single-shot 3D GRASE ASL sequence to optimally utilize the existing magnetization.

Material and Methods:

The behavior of the magnetization of spins with a given T_1 relaxation time after application of multiple inversion pulses can be modeled easily using the well-known Bloch-equation (see [2]). Using two inversion pulses the position of the rf-pulses can be chosen in a way that the magnetization of two compartments with different T_1 is zero at a given time TI. Unfortunately, the equations are impossible to solve analytically for arbitrary combinations of T_1 values. Therefore, we decided to solve the equations under the assumption that the ratio of the relaxation times is 5 (inspired by the T_1 times for grey matter and CSF). Then, the position of the inversion pulses can be expressed as:

$$\tau_{1,2} = TI + 5 \cdot T_1 \cdot \ln\left(\frac{1}{4} \cdot \left(\pm(E1-1) + \sqrt{2 \cdot \sqrt{13 + 12 \cdot E1 + 14 \cdot E1^2 + 12 \cdot E1^3 + 13 \cdot E1^4} - (E1-1)^2}\right)\right) \quad with\ E1 = e^{-TI/T1}. \qquad \text{(Eq.1)}$$

For practical use within the sequence the expression was evolved in a third order polynomial. The timing was determined so that the magnetization was nulled 100ms before readout since otherwise subtraction errors in the perfusion-weighted data occurred.

A clinical 1.5T scanner (Magnetom Sonata, Siemens, Erlangen, Germany) was used for imaging. Maximum gradient strength was 40mT/m with a slew rate of 200mT/m/ms. The resolution relevant parameters of the single shot 3D-GRASE sequence were: matrix size 64x41, reconstructed to 128x80, field-of-view 250mm x 160mm, nominal 16 partitions with 13% oversampling, partition thickness 4.5 mm, 5/8 Fourier encoding was used to reduce the number of measured partitions to 11. Thus, an almost isotropic resolution of 4 mm $\times$ 4 mm $\times$ 4.5 mm was achieved. Other parameters include: echo time TE=33 ms, repetition time TR=2500ms, total echo train length 410 ms, inter RF-spacing = 33 ms, bandwidth = 2170 Hz, off-resonance fat saturation pulse. Directly after the ASL preparation (non- and slice-selective inversion, respectively) a saturation of the imaging slice was performed. Perfusion-weighted images were acquired for different inflow times TI with and without BS with 10 repetitions for each TI resulting in an acquisition time of 50s per inflow time. The perfusion-weighted images were compared in terms of image quality and SNR.

Results:

Figure 1 shows one slice at seven different TIs with and without BS. Very high SNR could be observed in all data sets due to the efficient single-shot technique. Signal intensity of stationary spins was typically twice the intensity of the labeled blood. The SNR of BS images was about 10% higher than without suppression due to the better optimized dynamic range of the receiver hardware. Macro-vascular signal contribution appears to be higher on BS images.

Discussion and Conclusion:

A method was presented to improve the 3D acquisition of perfusion data by using single-shot 3D-GRASE readout combined with a BS technique. Efficient suppression of the stationary tissue and CSF was achieved over a wide range of TIs. The sequence yields high SNR, since the readout time per voxel is up to six times higher compared to conventional EPI or spiral-sequences. The proposed method allows fast isotropic acquisition of perfusion of almost the whole brain within less than 1 min.

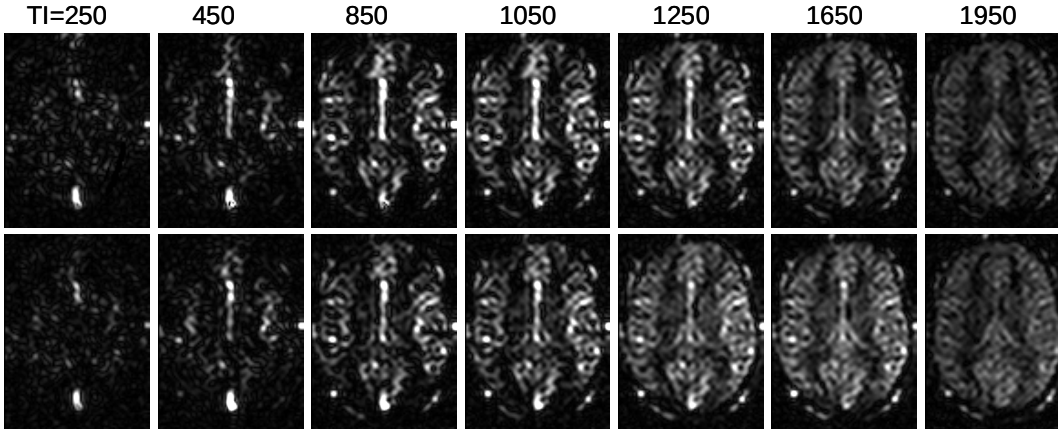

Fig.1: One out of 16 slices at different inflow times of the labeled blood with (top) and without (bottom) BS technique. The acquisition time of the 3D data set at each time step took 50s.

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References:

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