Improving the stability of T2 measurements in ASL experiments

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Introduction: Conventionally, Arterial Spin Labeling (ASL) is utilized to measure perfusion. The shortest echo time possible is typically used to achieve the best signal-to-noise ratio (SNR). Recently, these perfusion experiments were extended to include T2 measurements of the difference signal [1- 3], where the acquisition of data at different TEs is needed to sample the signal decay. This is a challenging task due to the limited SNR of ASL experiments. Usually, this leads to rather long scan times [1, 2]. Here, we present an ASL experiment, which allows sampling of the inflow curve of the labeled blood bolus at several echo times with no penalty in terms of measurement time compared to standard ASL. A multi-TE 3D-GRASE echo train is utilized providing high SNR as well as direct T2 estimates.

Materials and Methods: The ASL experiment was performed on a 3T scanner (Siemens Magnetom Trio), a 32 cannel coil, at two healthy volunteers (24 year female, 29 year male). The eight echoes were acquired at inflow times of 300 to 2700ms in steps of 100ms. The 3D-GRASE readout module was repeated seven times without the excitation rf pulse (Fig.1). This allows to sample the T2-decay of the signal in one shot and increases the stability of the measurement compared to the sequential measurement of different echo times as done before [1, 3]. The labeled blood bolus will travel down the vascular tree during the readout as well. Thus, the actual echo time will add to the true inflow time (TI) of each image and has to be taken into account for T2 calculation. In our case, we chose identical sample spacing for TE and TI to allow this correction (TE correction) to be done by a simple resorting of the data. For noise reduction the measurement was averaged two times. The central part of the brain was covered by eight slices with an isotropic spatial resolution of 3.3mm using a 4-fold segmented 3D-GRASE echo train. Total measurement time was 20 minutes.

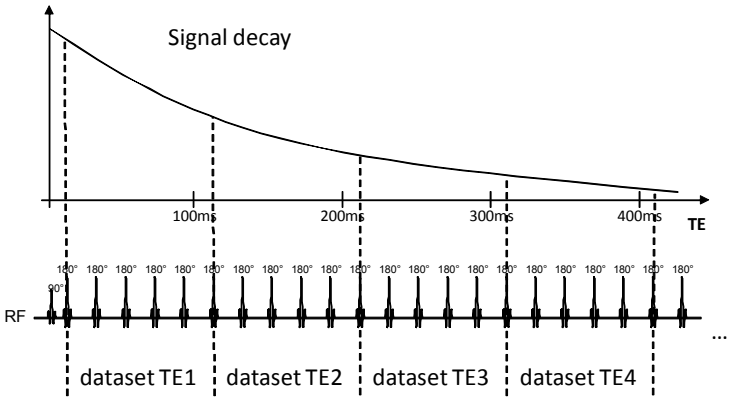

Fig. 1 Schematic principle of multi-TE 3D-GRASE sequence

Image analysis was done in an automated python pipeline in DEVIDE [4]. From the first echoes the bolus arrival time (BAT) is estimated for each voxel. The data is Gauss filtered (1.2 voxel spatially, 2 voxel in time), TE corrected and masked with a gray matter mask. A linear regression is done on the logarithmic intensity data over the echo time for each voxel and inflow time, if the BAT is smaller or equal to the inflow time. The results are calculated back to T2 maps.

Results: The fit is stable, failing in under 0.5% of the voxel. But more important is that also the r value is above 0.5 in 98% of the TE corrected cases and in 89% of the non corrected cases. For r values above 0.7 the advantage of the TE correction is clearly seen. 94% of the corrected data has r values above 0.7 while it is just 34% of the non corrected one. The TE correction stabilizes the T2 data while acquiring the echoes in one read out cycle reduces the physiological noise. Fig. 2 shows the percent increase of T2 values at 1000ms, 1700ms and 2200ms compared to the latest inflow time of 2700ms. The images show the good working gray matter masking as well as the stability of the fitting even at late inflow times. Generally, an increase of the T2 values is seen, which is steeper in the first 1000ms than in the time between 1000ms and 1700ms and to long TIs. In the visual cortex the increase is delayed compared to other regions since the labeled bolus arrives there later. The T2 values lay mostly between 100ms and 300ms.

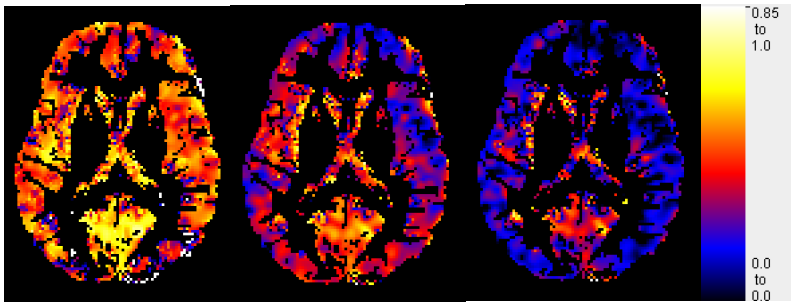

Fig. 2 percental maps of T2 increase at 1000ms, 1700ms and 2200ms

Discussion: The increase of T2 with increasing TI might be contributed to exchanges processes, where labeled blood spins are leaving the microvasculature and enter the extra-cellular space. Another explanation could be the nonlinear behavior of the background suppression technique used at different TIs. Further work is needed to determine the origin of the T2 increase.

A CPMG-echo train with a large number of refocusing pulses was used. It is well-known that a true T2 measurement using this approach can only be achieved for perfect 180° refocusing pulses. This will not be true in practice and will lead to a mixture of T2/T1 relaxation taking place during refocusing due to stimulated echoes. This is most apparent in outer slices due to the slab profile. Comparisons with sequentially acquired data did not show significant differences for inner slices (data not shown here).

A robust method was developed with clinical acceptable scan times of five minutes or even further if the resolution is reduced.

References:

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