Single TI PASL or Multi TI PASL for perfusion weighted fMRI?

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Introduction

Perfusion weighted fMRI has several potential advantages over BOLD imaging: it is related to a single physiological parameter (the cerebral blood flow(CBF)), it does not suffer from low frequency noise, and it benefits from an improved localization. Arterial spin labeling (ASL) enables a non-invasive measurement of CBF and is therefore frequently used for fMRI. However, the use of pulsed ASL (PASL) is hampered by shorter transit times during activation that limits the possibilities to quantify CBF or CBF changes.[1] Different approaches have been proposed to correct for this and one is the use of multi-TI-PASL that monitors the dynamic inflow and decay of labeled spins.[2] This is achieved by a Look-Locker read-out: a train of small angle pulses that probe the longitudinal magnetization as a function of inflow time (or inversion time (TI)). The signal-to-noise ratio of a single dynamic scan is too low to calculate CBF pixel-wise, therefore it is common to analyze each inversion time as a separate experiment. However, this approach is hampered by a low SNR, since the train of RF-pulses decreases the apparent T_1, resulting in an early loss of perfusion signal. Furthermore, the signal-to-noise ratio per single TI-image decreases due to the necessity to use smaller flip angles. Therefore, it is expected that the SNR of a single TI image out of a multi-TI-PASL sequence will have a lower SNR than a single TI PASL sequence. If multi-TI-PASL has indeed a lower SNR, the advantage of quantification of CBF may be less important than the disadvantage of a lower detectibility of activation. The goal of the current research is to compare the SNR of multi-TI-PASL with PASL, to investigate the influence on the identification of activated voxels, and to study whether the statistical power of multi-TI-PASL can be improved by averaging over inversion times.

Materials and Methods

Four subjects were included in this study. In all subjects two perfusion weighted fMRI scans were made. One scan was the single TI TILT technique (a single slice through the visual cortex with TI=1000 ms, FOV=240 mm, 64x64 matrix, slice thickness 8 mm, TR=3000 ms, TE=8.4 ms, flip angle 90°), the other scan the TURBO-TILT sequence (same parameters, except for TI = 200, 400, 600,…, 2600 ms, flip angle 35°). An 8 Hz inverting radial checkerboard was used as stimulus (5 periods of activation interleaved with 5 periods of rest, duration of both activation and rest period was 60 seconds). Post-processing was performed in SPM99 (smoothing with an 8 mm kernel and normal GLM-analysis with convolution of box-car function with the hrf as contrast of interest). A threshold of p=0.001 was adopted to identify activated voxels and the analysis was restricted to the visual cortex. For each volunteer the number of activated voxels of the TILT scan and of each inversion time of the TURBO-TILT sequence was determined. The overlap of activated regions of the TILT-scan and every inversion time of the TURBO-TILT-scan was calculated as twice the number of overlapping voxels divided by the sum of activated voxels in each of the two scans multiplied by 100%. Furthermore, the average t-value was determined over all voxels that were activated in the TILT-scan or for one or more inversion times of the TURBO-TILT scan. We investigated whether averaging of the TURBO-TILT scan over all inversion times between 600 and 1400 ms would improve statistical power. The mean t-value was again calculated, but now over all voxels that were active in the TILT-scan or the averaged TURBO-TILT scan.

Results

Figure 1 summarizes the results of this study. Comparing a single inversion time of the TURBO-TILT scan with the TILT-scan, showed a lower number of activated voxels, a lower mean t-value compared to the TILT-scan, and a low overlap with the activated regions of the TILT-scan. The total number of voxels identified as active on one or more inversion times was also lower than for the TILT-scan (data not shown). From 600 ms till 1400 ms a reasonable overlap with the TILT-scan and the highest t-values were observed, therefore we averaged these inversion times of the TURBO-TILT-scan to improve statistical power. The resulting mean TURBO-TILT showed a higher overlap with the activated regions of the TILT scan and a higher averaged t-value. After averaging of the TURBO-TILT sequence between 600 and 1400 ms, the number of activated voxels was comparable to the TILT scan and the average t-value was no longer significantly lower than the TILT-scan (tested by means of a paired t-test).

Discussion and conclusions

When performing a multi inversion time PASL-fMRI experiment, it is not *a priori* clear how to identify activated regions. Ideally, one would like to calculate the CBF for every dynamic scan and perform the analysis on the CBF-images, but the limited SNR impedes such voxel-wise quantification. Previous studies analyzed therefore each TI separately[1], but the SNR of a single inversion time of a TURBO-TILT sequence is lower than the SNR of TILT (see Fig.1), thus resulting in less statistical power. By averaging the inversion times between 600 and 1400 ms the SNR is increased to the same level as a TILT sequence. Inclusion of more inversion times would lower the statistical power due to the inclusion of more noise than signal (see the low t-values for these inversion times in Fig. 1) and would result in activations in the arterial system. After identification of activated voxels on the basis of the averaged multi-TI-PASL sequence the multi TI data can be used to quantify perfusion changes. Detection of active regions can thus equally well be performed on the basis of a multi-TI-PASL sequence than a PASL sequence with the additional advantage of the possibility to quantify CBF and CBF-changes.

[1]J.Hendrikse, Magn.Reson.Med. 50:429-433 [2]M.Günther, Mag.Reson.Med 46:974-984

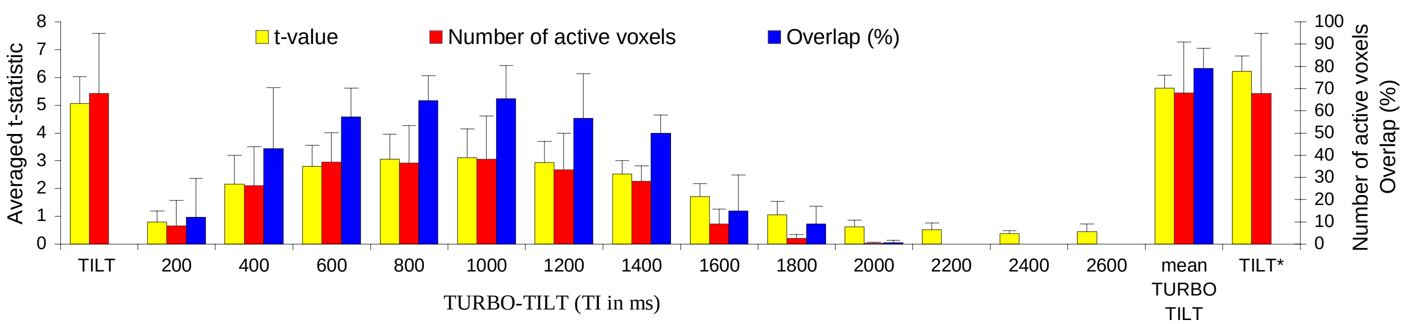

Figure 1: Average t-value (yellow bars) over all voxels that were activated (p<0.001) for the TILT scan or for one of the inversion times of the TURBO-TILT sequence. Red bars indicate number of activated voxels and blue bars indicate overlap with activated voxels of TILT scan (both scales on the right side). Mean TURBO-TILT corresponds to the TURBO-TILT scan averaged over all inversion times between and including 600 and 1400 ms. For Mean TURBO-TILT and TILT* the averaged t-statistic is calculated for all voxels that were active (p<0.001) in Mean TURBO-TILT or TILT. Error-bars indicate standard deviations.