Flow-weighted iVASO-DS for absolute arterial CBV quantification

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Introduction

Inflow vascular-space-occupancy with dynamic subtraction (iVASO-DS) [1] is a non-invasive MRI method for absolute arterial cerebral blood volume (aCBV) quantification. In the present study, mild flow-weighting (FW) gradients were added to the imaging readout. Comparison of experiments with and without FW gradients yields valuable information on the sources of iVASO-DS. Especially, the influence of fresh (i.e. non-inverted) blood, which is delivered by larger-scale arteries, is shown to be suppressed in this way.

Method

The iVASO-DS pulse sequence as described in Ref. [1] was implemented on a 3T MRI scanner (MedSpec 30/100, Bruker BioSpin, Ettlingen, Germany). Briefly, the iVASO-DS contrast is obtained by acquiring pairs of images, one (the null condition) with the inflowing blood nulled at the inversion time (*TI*), and the other (the control condition) without blood nulling. Two slice-selective inversion pulses (10 ms hyperbolic secant pulses) are applied in the control condition whereas a non-selective and a slice-selective inversion pulse are applied in the null condition. The thickness of the inversion slab was chosen to be 40% higher than that of the imaging slice to account for the different flipback efficiencies in the two conditions. For imaging, an EPI readout (bandwidth 100 kHz, matrix 64x64, TE 25 ms, FOV 192x192 mm^2) was used. Flow-weighting was introduced by a bipolar pair of gradient pulses along the *z*-axis ($b = 2$ s/mm^2).

Several experiments with *TI*/*TR* pairs that fulfill the blood nulling condition were acquired in 2 subjects. In addition, a reference scan (see below) and a scan without preparation pulses were acquired to correct for systematic errors and to relate the corrected difference signal to the equilibrium value, respectively. Based on theoretical analysis, the aCBV fraction was calculated from the relative corrected difference signal. Preprocessing included two-dimensional motion correction and spatial smoothing (5 mm Gaussian kernel).
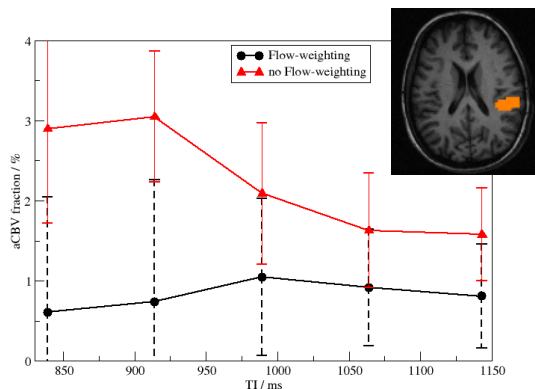

Fig. 1: *TI*-dependence of the aCBV fraction averaged in a ROI (cf. inset) of the middle cerebral artery territory. Errors represent the standard deviation of the differences of the control and null images.
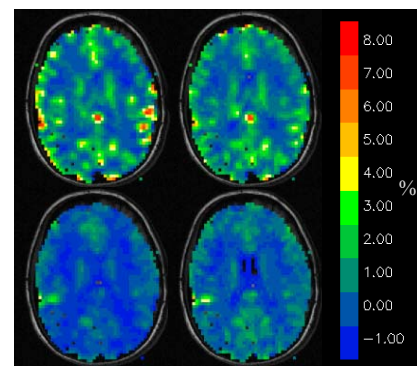

Fig. 2: Maps of the aCBV fraction as obtained without (top) and with FW (bottom) for *TI*/*TR* = 839/1269 ms (left) and *TI*/*TR* = 1143/3000 ms (right).

Results & Discussion

The procedure employed in this work differs from the original work [1] by correcting the systematic error of the iVASO-DS signal on a point-by-point basis by subtracting a reference scan acquired at minimum *TI* and long *TR*. Under these conditions, no iVASO-DS contrast is expected, and the maximum systematic error between control and null conditions can be estimated. The dependence of the aCBV fraction on *TI* obtained from iVASO-DS experiments with and without application of mild FW gradients is shown in Fig. 1. The curve without FW shows a significant decrease of aCBV with *TI* whereas no significant change of aCBV can be detected for the experiments with FW. Fig. 2 shows maps with and without FW for *TI*s of 839 and 1143 ms. The negative values in white matter indicate that aCBV might be slightly underestimated even after correction for systematic errors. In the experiment without FW, hot spots of the aCBV fraction of more than 5% appear at the shorter *TI* and disappear at the longer *TI*. This behavior can easily be explained by signals from larger-scale arteries. Such signals are destroyed by FW gradients which, for this study, are expected to remove contributions from arterial vessels with diameters above 0.2 mm [2]. In these vessels, the initially inverted arterial blood might already be replaced by non-inverted blood [1] if *TI* exceeds the arterial transit time from the neck. This fresh blood is not contributing to the iVASO-DS contrast and leads to a decrease of the measured aCBV fraction. Interestingly, the values of the aCBV fraction averaged over a gray matter mask differ between the experiments with (0.8%) and without (1.5%) FW even at the longest *TI*. Thus, the aCBV fraction obtained from iVASO-DS experiments not only depends on voxel size (by partial voluming) and *TI* (inflow time) but also on the effective flow-weighting of the imaging sequence.

References

[1] M. J. Donahue et al., J Cereb Blood Flow Metab 2010; 30:1329–1342.   [2] S.T. Francis et al., NMR Biomed 1999; 12:440-450.