Simplified perfusion quantification for arterial spin labeling in case of whole brain coverage

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Introduction Arterial spin labeling (ASL) allows for non-invasive mapping of the cerebral blood flow (CBF). However, accurate quantification is difficult, due to the complex physiology, which leads to complex models with many parameters that are difficult to assess.

Improvements in quantitative ASL include the fast multi time point approach with a Look-Locker readout [1,2]. The multi time point approach allows estimation of arterial transit time, time of trailing edge, and the apparent effective relaxation rate. A crucial parameter that remains difficult to assess, is the equilibrium magnetization of arterial blood, M0b. When a blood voxel from the sagittal sinus is used, a correction factor of about 1.7 is needed [2].

In this work, we propose a simple method to overcome the problem of M0b determination. When whole brain coverage is applied, the quantification of the CBF can be simplified considerably by normalizing the raw CBF map to the global flow through the main feeding arteries of the brain.

Methods Two volunteers were scanned, using PULSAR [3] with a Look-Locker readout. Imaging parameters are shown in Table 1. To cover the whole brain, 3 stacks of 6 consecutive slices were acquired. In volunteer 1, vascular crushing was applied with a threshold velocity of 3cm/s. In volunteer 2, no crushing was applied.

Velocity encoded phase-contrast cines were obtained in a transversal orientation in the neck, to assess the global flow through the brain feeding arteries. For this purpose, a triggered spoiled gradient echo sequence with flow encoding was used (see parameters in Table 1), which was performed twice, just prior to and after the ASL data acquisition to check for changes in the global flow during the measurement.

Traditional quantification by fitting the model of Buxton et al. [4] was performed in IDL 6.1 (Research System, Inc.). The CBF map was corrected for M0b by a semi-empirical correction factor of 1.6, which was previously found to yield perfusion that is comparable to PET results.

To explore the feasibility of our proposal, we compared the global flow as measured in the brain feeding arteries, with the integrated regional CBF over the brain volume, noting that these should be equal.

Table 1. Imaging parameters

	Voxel size (mm^3)	Flip angle (deg)	#Slices	ΔTI (ms)	#Repetitions	#Time points	Venc (cm/s)
ASL	4x4x8	35	6	220	30	13	-
Velocity encoded phase-contrast	0.9x0.9x5	10	1	-	2	25-30	90

Results and Discussion When vascular-crushing was applied, the global flow through the brain feeding arteries was very similar to the integrated CBF values (Fig 1). This means that the estimation of the CBF values can indeed be simplified by calibrating by the global flow, instead of by estimating the M0b and inversion efficiency, which are needed when the standard models are used. The slight underestimation of the current CBF values in the experiment with vascular crushing may indicate that crushing can spoil the labeled blood before exchange with the tissue.

When no crushing is applied, the huge signal in the large arteries will cause errors when the global flow is used to calibrate the CBF maps. Therefore, vascular crushing should be applied when aiming for quantitative CBF measurements. Masking high CBF values to filter out the vascular signal may also work, but is rather dependent on the choice of the threshold (Fig 1).

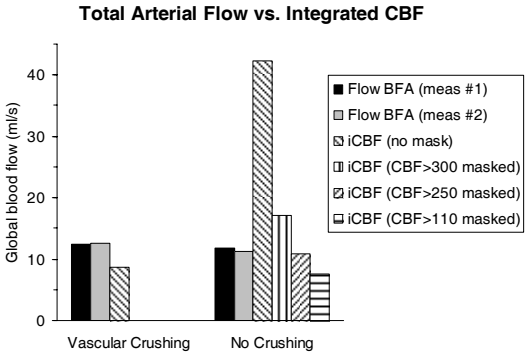

Figure 1. Comparison of the global cerebral flow obtained from the brain feeding arteries (flow BFA), and from integrating of the CBF over all brain voxels (iCBF). For the dataset without vascular crushing, several masks were applied to suppress the high signals from blood vessels.

In principle, the proposed method can also be applied to the method of Petersen et al. [2], in which both a crushed and a non-crushed experiment are combined to extract the arterial input function (AIF). After deconvolution with the AIF, the subtracted images (label minus control) result in an image in which the intensity is proportional to the CBF, but which needs estimation of M0b and labeling efficiency for quantification. This quantification can be simplified enormously by calibration by the global flow, when the ASL dataset has whole brain coverage.

Currently, the need for whole brain coverage limits the application of the proposed method. Increasing the number of slices in the Look-Locker or QUASAR scheme leads to increased saturation of the labeled blood during the transit time, which complicates the quantification. Fast 3D imaging methods in combination with velocity selective ASL (which reduces the transit times [5]) may overcome this problem.

References [1] Günther M, et al. MRM 46:974-984 (2001); [2] Petersen ET, et al. MRM 55:219-323 (2006); [3] Golay X, et al. MRM 53:15-21 (2005); [4] Buxton RB, et al. MRM 40:383-396 (1998); [5] Wong EC, et al. MRM 55:1334-1341.