ATLES: AuTomatic Labeling efficiency EStimation

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Target audience: MRI scientists and clinicians with interest in perfusion MRI

Purpose

Labeling efficiency (α) is the fraction of the initial longitudinal magnetization of arterial blood that is inverted by the labeling scheme in an Arterial Spin Labeling (ASL) experiment. In models used to quantify ASL images, it enters as a global scaling factor for Cerebral Blood Flow (CBF), and therefore is essential for absolute quantification. α is typically assessed by numerical simulation suited for different labeling schemes. In pseudo Continuous Arterial Spin Labeling (pCASL) a value of 0.85 is commonly used[1]. However different sources of variability, related to field inhomogeneities and physiologic state, are known to affect the actual value of α, especially in pCASL. This suggests to estimate α with a subject-specific approach. In a previous work[2], labeling efficiency in pCASL has been measured using a phase contrast (PC) MRI image, with an operator-dependent procedure. In this study an improvement of such method is proposed by the definition of an automatic procedure for labeling efficiency estimation (ATLES).

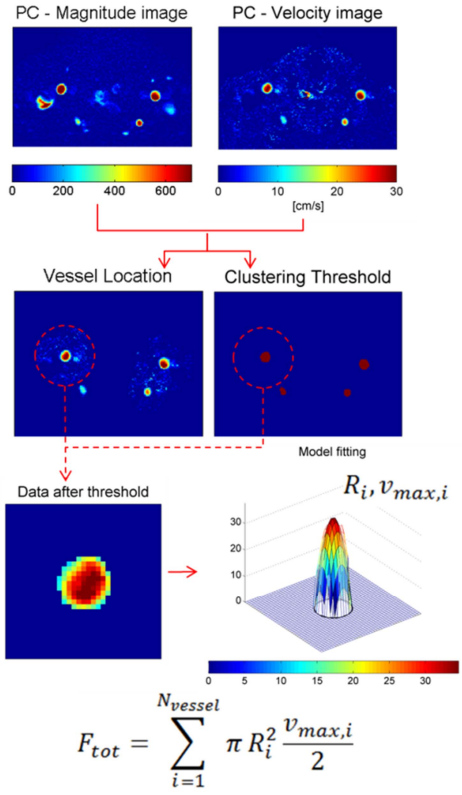

Fig 1: Full automatic pipeline of phase contrast images analysis for total blood flow quantification

Methods

Seven healthy subjects (26+/-3 years) were acquired on Philips 3T Achieva MR scanner. A static single slice PC acquisition was performed near labeling plane oriented perpendicular to brain feeding arteries, with voxel size 0.45x0.45x5mm^3, flip angle 15°, maximum encoding velocity 80cm/s, for a scan duration of 40s. A high resolution 3D T1-weighted image was acquired with an isotropic voxel dimension of 1x1x1mm^3. pCASL acquisition had the following parameters: labeling duration 1.8s, vascular crushing gradients (4 cm/s on z axis), 7 equally spaced post-labeling delay from 100ms up to 1800ms, 22 axial slices, voxel size 3x3x4mm^3, and 30 label/control pairs for averaging.
Following method described in[2], α can be estimated from the ratio of two different measures of total CBF, one obtained from PC images and the other from pCASL data, namely $CBF_{PC,tot}$ and $^{(unc)}CBF_{pCASL,tot}$. PC provides the necessary information to estimate $CBF_{PC,tot}$, once a measure of intracranial mass (M_b) is extracted from T_1-weighted acquisition using specific tools included in -FSL- (http://fsl.fmrib.ox.ac.uk/fsl/). In particular, the total blood flow to brain (F_{tot}) can be calculated from PC velocity image and then normalized by M_b to obtain $CBF_{PC,tot}$. PC images are analyzed by means of the proposed completely automated tool. Using both magnitude and phase (velocity) images, ATLES is able to detect location of brain feeding arteries, and evaluate F_{tot} adopting a model-based approach that exploits general assumptions on cylindrical shape of imaged vessels and laminar behavior of blood flow. The model fitting is preceded by a pre-processing step accomplished by means of cluster analysis. CBF from pCASL is quantified using Buxton model[3] neglecting the labeling efficiency, i.e. imposing α=1. A precise measure of total CBF from pCASL data ($^{(unc)}CBF_{pCASL,tot}$) is obtained by averaging CBF voxel-wise values, according to a metric based on uncertainty (CV) of estimates.

Results

In Fig. 1 different steps performed in the analysis of PC images are shown. Estimated values of F_{tot} from PC are in agreement with those reported in previous works[4]. Tab. 1 reports, for each subject, the three fundamental quantities used to estimate labeling efficiency of pCASL scheme: total blood flow, brain mass, and average CBF uncorrected for labeling efficiency. Also final values of labeling efficiency are reported, which show a good correspondence with[1,2].

Discussion

The additional acquisition of PC, that requires about 30s, allows the estimation of labeling efficiency within a frame that takes into account all the subject-specific factors that contribute to variability of α. Thus, this approach should be preferable than numerical simulations. However, since α results from the direct combination of three estimated quantities (F_{tot}, M_b, and $^{(unc)}CBF_{pCASL,tot}$), accuracy and reproducibility of methods used to estimate these parameters are essential for quantitative studies. Here, a robust method to obtain total CBF value from voxel-wise estimates provided by multi-TI ASL standard model is combined with a well-established software to calculate brain mass and a fully automatic tool for the quantification of total blood flow. This procedure is not affected by inter and intra-operator variability, allowing accurate and reproducible analysis suitable for comparison of results from multi-subject and multi-center studies.

	F_{tot}	M_b	$^{(unc)}CBF_{pCASL,tot}$	α
Control 1	651.7	1533.5	37.29	0.88
Control 2	946.3	1802.5	43.65	0.83
Control 3	814.2	1484.3	46.61	0.85
Control 4	826.5	1569.1	47.98	0.92
Control 5	896.6	1739.3	42.83	0.83
Control 6	879.8	1968.5	37.86	0.85
Control 7	642.3	1383.9	40.56	0.89
mean	**808.2**	**1643.3**	**42.39**	**0.86**
sd	**118.6**	**182.1**	**4.1**	**0.03**

Tab 1: Estimated parameters in labeling efficiency determination. Units are [ml/min], [g], [ml/100g/min], [%] respectively.

Conclusion

ATLES, an improved version of phase contrast normalization method for labeling efficiency estimation[2], is presented. The proposed tool is completely automated. As consequence, it is less time consuming and not affected by errors due to inter and intra-operator variability.

References

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