Semi-Automated Correction of Phase Errors in Optimized Pseudo-Continuous Arterial Spin Labeling

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Introduction: The optimized pseudo-continuous arterial spin labeling (Opt-PCASL) technique [1] is a variant of the original PCASL method [2] which offers high SNR characteristics while minimizing the loss in tagging efficiency caused by gradient imperfections and local field variations at the tagging plane. The optimization process includes a) interleaved acquisition of data with four (-90°, 0°, 90°, 180°) phase offsets, b) estimation of phase errors from the imaging plane based on ROIs that represent major vascular territories, and c) application of a constant phase offset to the RF pulses and gradient fields during tagging such that these errors are minimized. When optimal phase offset and gradient fields are determined, PCASL-based fMRI data can be acquired using only two (e.g. 0° and 180°) phases as is the case in the conventional PCASL tagging scheme, thereby achieving good temporal resolution and high tagging efficiency. In the previous implementation of Opt-PCASL [1], user intervention was required to define vascular territories for the estimation of phase errors. This process was time consuming and prone to user error, as it required subjective estimation of vascular territory maps. Here we present 1) a robust and accurate method of measuring phase errors and 2) a faster and automated scan process through a direct communication between the scanner and the post-processing module (Fig. 1) that eliminates user intervention. The proposed method makes use of the vascular territory imaging (VTI) method [3] to automatically select vascular territories.

Methods: One female and two male subjects were scanned on a General Electric 3T scanner (GE Healthcare, Waukesha, WI) using a 8-channel head coil. A 4-minute TOF scan was acquired to select the vessel locations for tagging. A 1.5-min VTI scan was then used to generate territory maps for the right carotid (RCA), left carotid (LCA), and vertebral (VA) arteries (Fig. 2A). An in-house post-processing algorithm was invoked automatically at the end of the VTI scan. Fractional maps of RCA, LCA, and VA were generated by normalizing the corresponding territory maps into their sum and each map was thresholded at 0.8 to generate VTI masks (Fig. 2B). Use of the VTI masks excluded voxels with significant mixing of blood from the feeding arteries. A PCASL calibration scan was then acquired to estimate the phase errors in each of the feeding arteries. This scan used 4 interleaved RF phase offsets and the following parameters: TR=3000 ms, TE=30 ms, reps=28, tag duration=1600 ms, post labeling delay=1000 ms, and scan time=1:24 min. At the end of the scan, a post processing algorithm was automatically called to estimate the phase errors using the VTI masks and the global RF phase offset and the gradient fields needed to correct them [1] were determined. These calibration values were automatically passed to the scanner through a shared configuration file for the next calibration scan. This iterative loop was repeated until the phase errors in all three vessel regions were less than 15° (Fig. 1). In one subject, a baseline CBF data set was collected (reps = 60) with and without the optimized parameters.

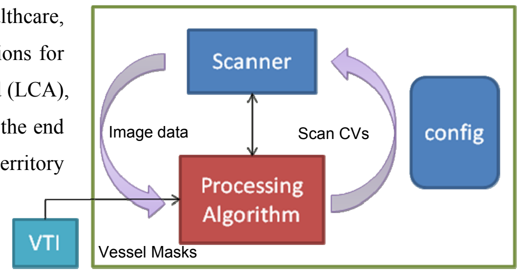

Fig. 1. *A schematic of iterative scan process for phase error correction.*

Results & Discussion: In all three subjects, the phase errors at the three tagging locations were reduced below 15° after one iteration. Fig. 2A is a sample VTI image from Subject 3. Fig. 2B shows the RCA (red)/LCA (green)/VA (blue) VTI masks generated based on Fig. 2A. Note that the algorithm excluded a large segment of the posterior region due to the mixing of blood supplied by RCA and VA. With the prior manual definition of vascular territories, many of the voxels with significant mixing of blood would have been assigned to the VA, leading to inaccurate estimation of the phase error. Figs. 2C and D are the measured phase errors before and after one optimization cycle. Figs. 2E and F are the temporal SNR maps from baseline CBF scans of Subject 1, showing a marked improvement (E = before; F = after optimization).

	Subject 1		Subject 2		Subject 3	
	Before	After	Before	After	Before	After
RCA	-24.1	8.61	-17.69	5.18	-30.34	8.72
LCA	-16.38	5.49	-4.62	3.62	-20.04	10.71
VA	-29.20	14.51	-26.39	-4.96	-47.15	-2.38

Table 1. *Phase errors (deg) before and after one calibration step.*

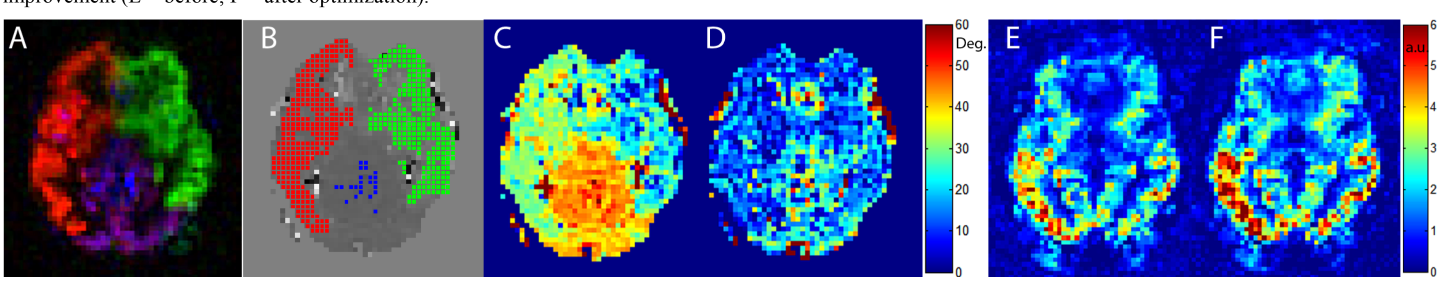

Fig. 2. *A: A sample VTI map. B: VTI masks corresponding to RCA, LCA, and VA territories. Absolute value of estimated phase errors before (C) and after (D) calibration. Temporal SNR of baseline CBF maps acquired (E) before and (F) after calibration.*

Conclusion: We have implemented a semi-automated optimization procedure, which incorporates an objective measure of phase errors and requires minimal user intervention. This approach is expected to facilitate the use of the Opt-PCASL technique for quantitative fMRI studies.

References: **1.** Jung Y et al. 17th ISMRM (Abstract 1578). **2.** Dai W et al. MRM 60:1488-1497. **3.** Wong EC. MRM 58:1086-1091, 2007.