2-shim or not 2-shim, that is a question in pseudo continuous arterial spin labeling.

Wouter M Teeuwisse[1,2], Sophie Schmid[1], Michael Helle[3], and Matthias van Osch[1]

[1]C.J. Gorter Center for High Field MRI, Leiden University Medical Center, Leiden, ZH, Netherlands, [2]Leiden Institute for Brain and Cognition, Leiden, ZH, Netherlands, [3]Innovative Technologies, Research Laboratories, Philips Technologie GmbH, Hamburg, Germany

Purpose.

In recent years, Pseudo Continuous Arterial Spin Labeling (pCASL) has proven itself as a robust method for measuring brain perfusion and its application in the clinical arena is rising. Although general parameter settings of this technique are by now well established and consensus hereon is reached[1], there are still more subtle issues that remain to be explored for further optimization. One of these issues concerns shimming of the B0 field for optimal homogeneity. Already recognized as indispensable in the fast imaging techniques applied in ASL, such as EPI or 3D-GRASE, B0 homogeneity is also known as an important factor that affects the efficiency of the labeling process. Because the pCASL labeling slab may be positioned 10 – 15 cm inferior of the imaging stack center, the question arises whether shim settings optimized for imaging are still adequate for labeling or that optimal labeling efficiency demands separate shimming at the level of the labeling slab. Although this is subject to discussion within the ASL community and literature for some time[2, 3], it has not been addressed in detail yet. Therefore the aim of this study is to evaluate whether implementation of dual-shim pCASL, with separate shim settings for imaging and labeling, performs better than single-shim pCASL in which shim settings are optimized on the imaging stack and used during labeling also.

Methods.

Seventeen healthy volunteers (age 31.2 ± 9.5 y; 9f, 8m) were scanned at 3T (Achieva, Philips Healthcare) with a 32-channel head coil. pCASL comprised labeling duration 1.8 s, post labeling delay 1.8 s, labeling with 21° Hanning pulses with 1.2 ms peak-peak interval and background suppression with saturation preceding labeling and hyperbolic secant pulses at 1.825 and 3.110 s after start of the labeling. Images were acquired with single shot GRE-EPI with TR 4263 ms, TE = 14 ms, SENSE 2.5, EPI factor 35, 80 x 80 matrix, 17 slices, slice gap 0 mm, resolution of 3 x 3 x 7 mm, 4:58 min. This scan was acquired with 1st order shimming on imaging only (single-shim) and with two dedicated, 1st order shim settings for labeling and imaging (dual-shim). Typical positioning of imaging stack and labeling slab is shown in figure 1. For data analysis two more scans were acquired with a geometry identical to that of the pCASL scans: an M0 measurement (TR/TE = 2000/12 ms, 6 averages, 14 s scan time) for CBF quantification according to the ISMRM white paper[1] and regional perfusion imaging[4] (RPI) to enable identification of left-, right- and posterior flow territory of the brain. Single- and dual-shim scans were registered to the RPI scan using FSL (FMRIB Analysis Group, Oxford, UK). Flow territory maps were used for masking which enabled calculation of mean gray matter CBF and mean temporal SNR (tSNR) per territory. Because B0 inhomogeneities may lead to difference in labeling efficiency between arteries, the left-right asymmetry in CBF was evaluated, expressed as $|CBF_L - CBF_R|/\{(CBF_L+CBF_R)/2\}$.

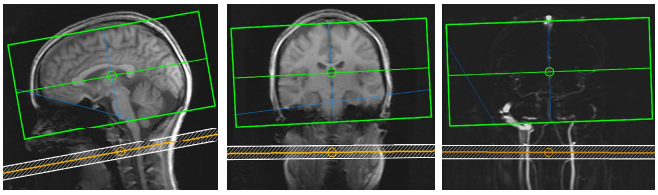

Figure 1. Typical planning applied in this study. The labeling slab is positioned such that it intercepts with the v3 segment of the vertebral arteries.

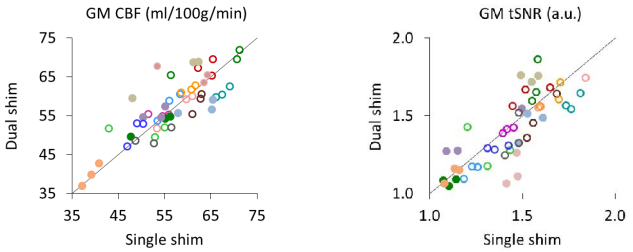

Figure 2. Comparison of results for single- and dual-shim pCASL for CBF (left) and gray matter tSNR (right). Three data points per subject represent the mean value for left-, right- or posterior flow territory. Filled markers indicate subjects with dental works that contain metal.

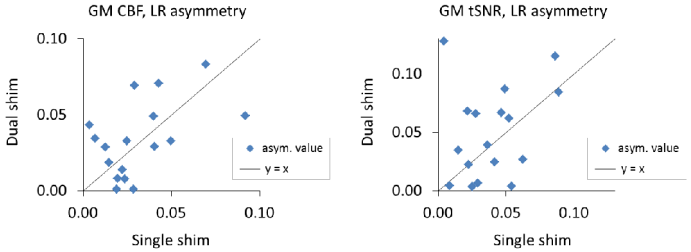

Figure 3. Comparison of results for single- and dual-shim pCASL evaluating asymmetry between the left and right flow territory gray matter CBF (left) and tSNR (right).

Results and discussion.

Figure 2 shows the results for CBF and tSNR in three flow territories in 17 subjects. Statistical testing confirmed no significant difference between the single- and dual shim approach. This holds also true when analysis is restricted to subjects with higher chance on B0 disturbance due to dental works that contain metal such as amalgam fillings, crowns, or orthodontic wires (indicated with filled markers). Similarly, no significant difference in LR-asymmetry was found. A limitation of this study is that only a labeling pulse interval of 1.2 ms was evaluated. It can be hypothesized that a longer pulse interval renders the labeling efficiency more vulnerable for B0 field disturbances due to an increasing mismatch between RF pulse phase and the phase buildup of spins traversing the labeling slab. Also the effect of dual shimming was only evaluated with 1st order shimming. When higher order shimming is applied, a single-shim approach may even increase B0 inhomogeneity at the level of the labeling slab.

Conclusion.

Using 1st order shimming, the addition of dedicated shimming during labeling has no significant effect on CBF or tSNR in pCASL. This may prove different when an RF pulse interval > 1.2 ms or higher order shimming is applied.

References. 1) Recommended Implementation of Arterial Spin Labeling Perfusion MRI for Clinical Applications. ISMRM Perfusion Study Group and the European ASL in Dementia Consortium; 2) Jahanian, NMR in Biomedicine 2011, 24(10), 1202-1209; 3); Jung, Magn Reson Med. 2010; 64(3):799-810; 4) Wong, Magn Reson Med 58:1086–1091 (2007)