ASL inversion efficiency for three methods and two magnetic fields

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Target audience: MRI Methodologists.

PURPOSE: Arterial Spin Labeling (ASL) methods requires an estimate of the inversion efficiency (IE) to quantify blood flow [1]. The purpose of this study is to estimate IE for three methods (pulsed ASL (PASL), Continuous ASL (CASL), and pseudo-continuous ASL (pCASL)) and two magnetic fields in the context of preclinical imaging.

METHODS: Male Wistar rats were used for this study (n=8, 330 ± 15g). MRI experiments were conducted on 4.7T and 7T horizontal scanners (Bruker) with a volume transmit/surface receive coil configuration and a gradient coil capable of generating 660mT/m with a 114µs rise time. A global first and second order shim was performed, using the volume coil for signal reception. For PASL, a selective and a global inversion profiles were acquired (hyperbolic secant inversion shape: duration/bandwidth = 15ms/5190.7Hz). The IE was computed using Eq. [1]:

$$\alpha = \frac{1 - \Re\left\{\frac{FFT(S^{inv})\times\exp(TI/T_1)}{FFT(S^{ref})}\right\}}{2} \quad (1) \qquad \alpha = \frac{M_a^0 - M_a}{2M_a^0} \quad (2)$$

where S^{inv} is the MR signal with inversion, S^{ref} is the MR signal without inversion, TI is the inversion time and T_1 is the tissue longitudinal relaxation time (measured with a selective inversion pulse and an EPI acquisition module, 18 inversions). For CASL and pCASL, a Gradient Echo Flow Compensated (GEFC) sequence (TR/TE=225ms/5ms, matrix=256x256, FOV=30x30mm) with a labeling module (CASL: labeling duration=200ms, postlabeling delay<1ms; pCASL: pulse duration=300µs, interpulse delay=600µs, labeling duration=200ms, postlabeling delay<1ms) was used to measure blood magnetization (cf. Fig.1) in label and in control conditions. The B_1 amplitude was chosen so as to obtain the best IE at each magnetic field.

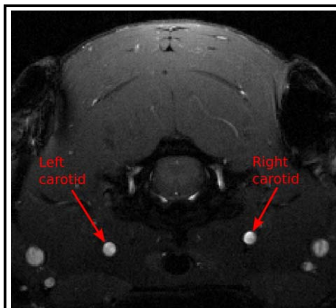

Fig. 1: GEFC image at 7T, showing where the signal was measured.

The IE was computed using Eq. 2 [2], where M_a^0 is equilibrium magnetization of arterial blood and M_a is magnetization of arterial blood after inversion. An unpaired t-test was used to compare data between modalities or between magnetic fields.

RESULTS and DISCUSSION: Fig.2 shows the IE for each method and each magnetic field. As expected, the IE of PASL, which uses an adiabatic inversion pulse, is close to 100% and the IE values are comparable between magnetic fields, despite the reduction in blood T2 between 4.7T and 7T. The IE for CASL is 87.6±0.7% at 4.7T and 85.4±0.4 % at 7T. For pCASL, the IE decreases to 74±1 % at 4.7T and 47±2 % at 7T. The IE for CASL is lower than that of PASL, in agreement with the literature. Similarly, the IE of pCASL is lower than that of CASL. As the magnetic field increases, the decrease in IE is larger for pCASL (-25%; p<0.001) than for CASL (-2.2%; p=0.07). This difference might be explained by the sensitivity of pCASL to the magnetic field homogeneity in the labeling area [3]. For check if shim errors imply this decrease of inversion efficiency in pCASL, we have realized preliminary experiment (3 rats at 4.7T and 1 rat at 7T). This experiment is to measure field inhomogeneity around carotid on mapfield acquisition, calculate the residual gradient and correct this one during inversion pulse. The results are around 84% at 4.7T (n=3) and 83% at 7T (n=1) for IE of pCASL.

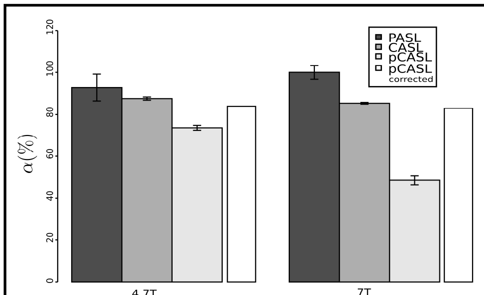

Fig. 2: Inversion efficiency (in %) of PASL, CASL and pCASL methods at 4.7T and 7T. Mean±Standard error of the mean.

CONCLUSION: The IE of PASL is constant between 4.7T and 7T, while the IE of CASL and pCASL decrease as the magnetic field increases. The IE of pCASL appears more sensitive to the magnetic field than that of CASL, but with a correction of shim during inversion: IE of pCASL seem reach to IE of CASL. Further experiments are required to verify this assertion on more rats and his reproducibility. The good IE obtained at 7T is promising for human studies with ASL at high magnetic fields.

REFERENCES: **1.** Alsop DC, Detre JA. Reduced transit-time sensitivity in noninvasive magnetic resonance imaging of human cerebral blood flow. *J. Cereb. Blood Flow Metab*. 1996;16(6):1236–1249. **2.** Zhang W, Williams DS, Koretsky AP. Measurement of rat brain perfusion by NMR using spin labeling of arterial water: in vivo determination of the degree of spin labeling. *Magn Reson Med*. 1993;29(3):416–421.**3.** Jahanian H, Noll DC, Hernandez-Garcia L. B(0) field inhomogeneity considerations in pseudo-continuous arterial spin labeling (pCASL): effects on tagging efficiency and correction strategy. *NMR Biomed*. 2011.