Pseudocontinuous ASL (pCASL) Combined with EPI, RARE and TrueFISP for High Resolution Multi-Orientation Mouse Brain Perfusion Imaging

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Introduction: Mouse models of human brain diseases (tumor, stroke, Alzheimer’s disease ...) are extensively studied with long scan time multimodal MR protocols that include functional, metabolic and structural approaches. To further describe the pathologies, there is then a real need for a high resolution, sensitive method which allows assessing quantitative whole brain perfusion within a reasonable scan time.

The pseudo-continuous ASL technique recently applied at very high field for mouse brain perfusion measurement has demonstrated a sensitivity gain of ~40% compared to pulsed ASL performed with an optimized presat-FAIR sequence and a high capability for multislice perfusion imaging. However, this previous work, performed with a large volume coil required thirty minutes of data averaging to obtain reliable CBF maps in the axial plane only. Moreover, the pCASL inversion efficiency was not calculated but estimated as a first approximation by comparison of the CBF values obtained with pCASL and FAIR. The proposed work presents a significant improvement of the previous study by allowing the calculation of the pCASL inversion efficiency and by the acquisition of multislice CBF maps in coronal and axial orientations within a reduced scan time.

Methods: Experiments were carried out on an 11.7T vertical MR system (Bruker, AV 500WB, transmitter/receiver volume coil: 2 cm, length 3 cm) on anesthetized mice (C57BL/6J, 10 weeks, weight 25±1g, N=5).

ASL perfusion imaging was performed with the ubpCASL method optimized for mouse brain perfusion imaging (3 slices, thickness 0.75mm, TE=9ms, matrix 128x128, FOV 2.5x2.5cm2) for axial images, whereas for the coronal orientation, a 2-shot RARE sequence, less prone to susceptibility artifacts was preferred (2 slices, magnetization differences, ΔM,ubpCASL, were averaged 10 times). The values might be slightly underestimated (3-5%) due to the blood relaxation effect (T1g=2.1s) which occurred during the transit time (estimated to ~70-100ms for a mean blood velocity of ~10-15cm/s in the carotids and a distance between the inversion plane and the imaging slab of 1cm) for each orientation, no slice effect or inversion efficiency loss was observed across the slices, resulting in a uniform sensitivity of the ΔM,ubpCASL maps (fig 2, ubpCASL-EPI and fig 3, ubpCASL-RARE). Typical axial and coronal CBF maps show classical heterogeneous blood flow distribution within different brain structures. Quantitative analyses (mean value ± standard deviation) were performed in ROIs selected in highly perfused areas (thalamus (Th), CBF=230±27 mL/100g/min, septal nucleus (Ls), CBF=224±35 mL/100g/min, cortex (cx), CBF=197±24 mL/100g/min) and moderately perfused areas (caudate putamen (Cp), CBF=166±21 mL/100g/min, hippocampus (h), CBF=148±25 mL/100g/min, dentate gyrus (DG), CBF=140±18 mL/100g/min). The mean in-ROI variations and group standard deviations represented ~15% and ~12% respectively, highlighting the good accuracy of the ubpCASL method.

Discussion: This work presents the use of the ubpCASL module in combination with fast imaging sequences for the acquisition of high resolution quantitative mouse CBF maps within a short scan time protocol. The measurement of the ubpCASL inversion efficiency required less than 1 minute and the image acquisition time of the FISP sequence (67ms), shorter than the blood transit time (70-100ms), insured minimal underestimation of β. The 2-shot EPI sequence produced high SNR, good quality images in the axial direction. RARE imaging, although less sensitive, was a good alternative to EPI for the acquisition of coronal images, free of susceptibility artifacts. For both ubpCASL-EPI and ubpCASL-RARE, 10-min of ΔM,ubpCASL averaging was sufficient to obtain accurate quantitative CBF maps (~15% of in-ROI variations) with 200x200µm2/pixel of resolution. On the overall, 25 min were required for the whole protocol, which was performed with a standard volume coil (Ø 2cm, L=3cm) well-suited for mouse brain multimodal studies.