Comparison of four quantitative pulsed ASL methods for mouse brain perfusion MRI

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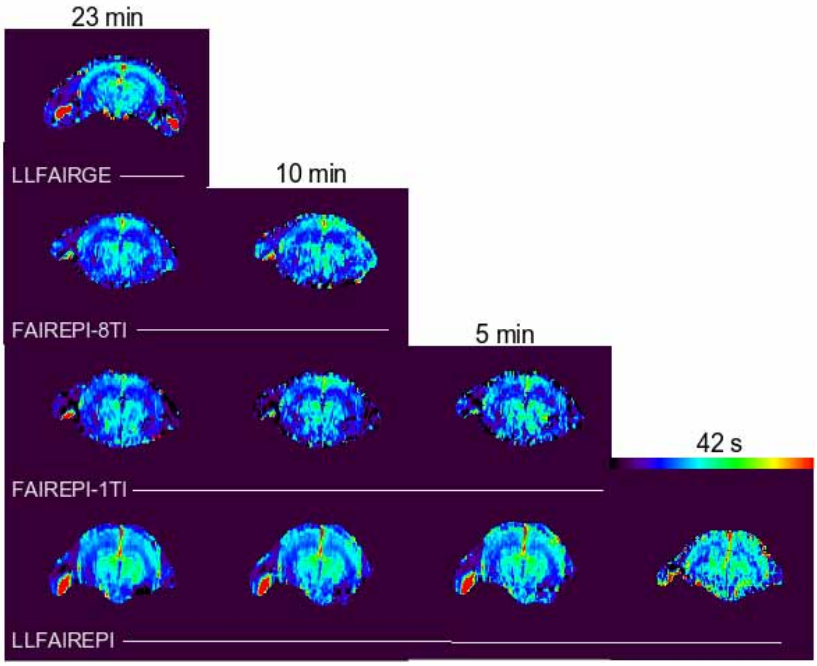
Introduction

Pulsed arterial spin labeling (ASL) is an attractive method for rodent brain capillary blood flow (CBF) quantification, although there is interest in sensitivity optimization, particularly for serial measurements on single animals, which require temporal resolution. In this study, the performance of two FAIR ASL techniques and of two Look-Locker-FAIR ASL techniques was compared for quantitative mouse brain CBF mapping at 4.7 T.

Materials and Methods

Spin-Echo FAIR-EPI (1) with 8 inversion times (FAIREPI8), Spin-Echo FAIR-EPI with a single inversion time (FAIREPI1) as well as Look-Locker-FAIR-EPI (LLFAIREPI) (2) and Look-Locker-FAIR-GE (LLFAIRGE) (3) sequences with 50 inversion times (ΔTI=150 ms, α=11°) were implemented with equal spatial resolutions (195x390µm, 1mm slice thickness) and equal FAIR labeling modules on a Bruker 4.7T horizontal imaging system equipped with a homogeneous rf excitation coil and a decoupled surface reception coil. Measurements with all methods were carried out sequentially on the brain of each of 10 healthy mice anesthetized with 1.8% isoflurane. Acquisition times up to 23 minutes (minimum acquisition time for LLFAIRGE) were allowed equally for every method by adapting the number of accumulations for techniques with shorter minimum acquisition time. Because all measurements were quantitative, an additional T1 measurement was necessary for the calibration of FAIREPI1. This was accomplished using a separate Inversion-Recovery EPI scan with 8 TI values and included in the evaluated FAIREPI1 measurement time. From all methods and all animals, CBF maps were obtained by using a one-compartment model and a pixel-by-pixel fitting approach (4). The resulting CBF maps were compared at equal measurement times and with lower measurement times for the EPI methods.



Results

The figure shows representative perfusion maps obtained with each method at different acquisition times. The table shows regional CBF and signal-to-noise ratio (SNR=CBF/SD_{ROI}(CBF)) values measured with the four methods at 23 min acquisition time.

Discussion

All methods gave good reproducibility and similar group variabilities of CBF. Image distortions were present in all EPI maps. LLFAIREPI gave the highest signal-to-noise ratio, but also the highest SNR group variability. At lower EPI measurement times down to 5 minutes, no significant changes were seen in absolute CBF or SNR within each technique (values not shown). This indicates that at long acquisition times, other than true rf noise aspects contribute to the SNR measured in the maps. However, further shortening the acquisition time to its minimum of 42s for LLFAIREPI led to a decrease of SNR by about one half. An interesting finding is that the SNR obtained with LLFAIREPI at 42s is as high as that obtained with FAIREPI1 after 5min. It has to be mentioned that the sensitivity of FAIREPI1 is reduced mainly by the need of a calibration scan, which for certain experiments can be carried out only once. The Look-Locker techniques overestimated CBF compared with classical FAIR-EPI. This can be attributed to bulk flow in arterioles and T2 effects, respectively. Due to isoflurane anesthesia, all CBF values are high compared with literature data.

group av ± SD (n = 10)	Thalamus		Hippocampus		Cortex	
	CBF	***SNR***	***CBF***	***SNR***	***CBF***	***SNR***
LLFAIRGE	449±34	5.2±1.3	278±22	4.7±1.2	306±44	7.1±2.0
FAIREPI-8TI	372±31	5.6±1.4	225±34	4.0±0.6	258±48	5.7±1.8
FAIREPI-1TI	355±29	4.8±1.1	214±22	4.3±0.9	270±30	4.5±1.4
LLFAIREPI	464±24	7.7±2.7	309±32	7.8±2.9	317±46	11.4±4.0

Conclusion

Due to their good performance at short acquisition times, both LLFAIREPI and FAIREPI1 are interesting candidates for serial measurements during the same experiment. From this point of view, LLFAIREPI has the additional advantage that the T1 measurement is inherent, and that its sensitivity was superior to that of the other techniques. Group variations of SNR were, however, higher with this technique compared with FAIREPI1. No advantage of measuring and processing varying TI values could be demonstrated here between FAIREPI8 and FAIREPI1. Due to its long minimum acquisition time, LLFAIRGE is only advantageous in studies where B0 inhomogeneities play an important role.

(1) Kim et al, Magn Reson Med. 1995; 34:293-301, (2) Günther et al, Magn Reson Med. 2001;46(5):974-84, (3) Kober et al, Magn Reson Med. 2004;51(1):62-7, (4) Pell et al, Magn Reson Med. 1999;41:829-840