A comparison of FAIR and CASL perfusion imaging in mice

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Introduction

Arterial spin labelling (ASL) techniques provide a non-invasive method for measuring perfusion. Here we present a quantitative comparison of continuous and pulsed spin labelling (CASL and FAIR respectively) in the mouse brain. In principle the difference between the control and the tag image is linearly proportional to CBF for both perfusion techniques. However, the quantification of CBF is complicated by several possible systematic errors, of which the arterial transit time is the most important; these parameters may also change during abnormal conditions such as ischemia. The aim of this study is to compare the performance of the two routinely used sequences, both for normal flow rates and during ischemia, when perfusion is low.

Methods

Animals 8 C57B×CBA mice were anaesthetised with 2.5% isoflurane and maintained on 1.3-1.7% isoflurane with 100% oxygen. The middle cerebral artery was occluding using a intraluminar thread, and animals were scanned at 2 and 24 hours after occlusion.

MRI Coronal EPI images were obtained on a 2.35T horizontal bore SMIS MR scanner approximately 0.5 mm from bregma with FOV 32x16 mm, a 2 mm slice, and 128 × 64 pixels. FAIR: Short repetition time FAIR sequence[1], non-selective inversion or a selective FOCI inversion pulse over a 5 mm slice, delay time 1300 ms, TR 1.5 s, and 22 averages. CASL: transit time insensitive CASL[2], interleaved adiabatic inversion labelling and control measurements, post-labelling delay time 500 ms, TR 1 s, and 22 averages. T_{1sat} and T_1: IR-EPI in the presence and absence of an off-resonance pulse equivalent to the CASL labelling/control pulse.

Data processing 4 ROIs were selected (left and right cortices and basal ganglia) in each animal for further analysis. FAIR: the ssIR data were used to fit for M_0, T_{1app} and α. These values were then used to fit the magnetisation difference for CBF[1]. Assumptions: T_{1a} (T_1 of arterial blood) = 1.5 s[1], λ (blood/brain partition coefficient) = 0.9. CASL: T_1, T_{1sat} and M_0 were fitted using the IR data; subsequently these values were used to fit the magnetisation difference to the equation in Alsop *et al.*[2] for CBF. Assumptions: T_{1a} = 1.5 s, λ = 0.9, efficiency of the spin labelling pulse = 0.71 (previous results; data not shown).

Transit times FAIR was assumed to be transit time insensitive. CASL: arterial transit time cortex 440 ms, basal ganglia 290 ms (previous results; data not shown), tissue transit time 1.5 s. Transit time correction (see results): CASL: cortex 800 ms, basal ganglia 600 ms, based on previous rat studies[3]. FAIR: cortex 500 ms, basal ganglia 500 ms.

Results and discussion

The data for all ROIs are shown in Fig 1A (♦), together with the line of equality. No differences were observed between cortices and basal ganglia; therefore we grouped all data together for further analysis. Fig. 1B shows the difference versus mean of the two techniques[4]. For normal perfusion rates (>100 ml/100g/min) there is an excellent correlation between the CASL and FAIR data (r = 0.96). The mean difference between the techniques is negligible, with a 95% confidence interval of –30 to +31 ml/100 g/min between the two methods for any given measurement.

In the case of compromised CBF however, there is a marked discrepancy between the techniques, with FAIR showing little sensitivity to different flow rates, in agreement with earlier reports[1]. This is most likely due to increased arterial transit times during occlusion, which would render the assumption that the technique is transit-time insensitive invalid. Therefore, we included a transit time correction in the FAIR and CASL calculations (□) for the ROIs with low CBF. The correspondence between the techniques is improved, though there is still a marked difference between the techniques, indicating that either the FAIR transit time during occlusion is even larger than estimated, or there are other confounding factors influencing the measurement. Further studies using transit-time insensitive sequences such as multi-TI FAIR or QUIPSS II[5] are needed to investigate this phenomenon.

In conclusion CASL with a post-labelling delay and FAIR show excellent agreement for normal flow rates, indicating that under these conditions the FAIR transit time is negligible. However, in the case of perfusion abnormalities, CASL appears to be more sensitive to low flow rates.

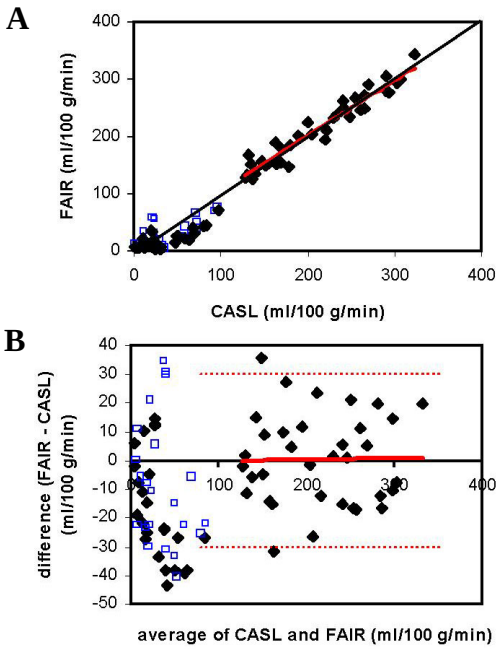

Fig. 1. A. CASL and FAIR data (♦), with line of equality and regression line for high CBF (>100 ml/100 g/min). □ denotes transit time corrected data. B. Difference versus mean of the two techniques, with 95% limits of agreement and regression lines for high CBF (>100 ml/100 g/min).

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