In Vivo Measurement of the Longitudinal Relaxation Time of Arterial Blood (T_{1a}) in the Mouse using a Pulsed Arterial Spin Labeling Approach

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INTRODUCTION

The longitudinal relaxation time of arterial blood water (T_{1a}) is a parameter that is required for the quantification of cerebral blood flow (CBF) using arterial spin labelling (ASL) techniques. However, T_{1a} is difficult to measure *in vivo*, due to the high speed of blood flow through the arteries and the small size of the arteries (particularly in small animals) which causes partial volume effects within voxels. Further, *ex vivo* measurements do not exactly replicate the *in vivo* conditions, and therefore may provide incorrect results. In this work, we have developed and applied a method based on pulsed ASL for measuring T_{1a} *in vivo*. The advantage of this approach is that it uses differences in tissue magnetisation to estimate T_{1a}, thereby eliminating the requirement to image and isolate intravascular blood signal.

METHODS

The FAIR technique with a global pre-saturation pulse was used, as has been described previously (1). With this sequence, assuming all non-selective saturation and inversion pulses are truly global, the FAIR difference magnetisation ΔM is described by:

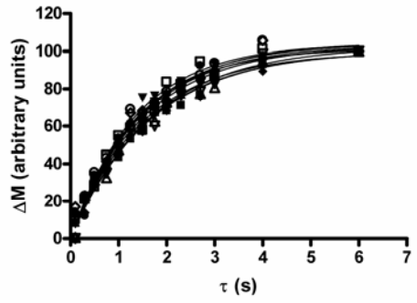
$$\Delta M(TI,\tau) = \frac{2M_0\alpha_0 \frac{f}{\lambda} e^{-\delta/T_{1a}}}{\left(1/T_{1app} - 1/T_{1a}\right)} \left(e^{-(TI-\delta)/T_{1a}} - e^{-(TI-\delta)/T_{1app}}\right)\left[1 - e^{-\tau/T_{1a}}\right] \qquad \{1\}$$

where TI is the inversion time, M_0 is spin density, α_0 is the inversion efficiency, f is CBF, λ is the blood:brain partition coefficient, δ is the transit time, T_{1app} is the apparent tissue T_1 following slice-selective inversion and τ is the time delay between the global pre-saturation and the subsequent inversion pulse. It can be seen from the last term of equation {1} that if measurements of ΔM are made over a range of τ, the data should follow a simple monoexponential recovery with T_{1a} as the time constant.

MRI studies were performed on anaesthetised adult male CD1 mice (n=5, 30-35g) using a 2.35T horizontal magnet interfaced to a SMIS console. RF excitation pulses were transmitted via a volume coil (6cm length) and received by a separate passively decoupled single loop surface coil (15mm diameter). FAIR images were acquired using single-shot spin echo EPI. A train of 4 adiabatic half sech pulses, each followed by a spoiler gradient, was used for global pre-saturation. FOCI inversion pulses (2) were used for efficient spin labelling and optimal slice definition. FAIR image pairs were acquired with a TI of 1.3s and the following values of τ (s): 0.1, 0.3, 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2, 2.3, 2.7, 3, 4, and 6. The acquisition order was randomized and different for each animal. Imaging parameters were: slice thickness = 2mm; image matrix size = 128×64; field of view = 32×16mm^2; TE = 36ms; N_{av} = 32. The total acquisition time for all τ values was approximately 55 minutes. A bipolar gradient pulse (b ≈ 17s/mm^2) was used to eliminate intravascular signal from large blood vessels. Analysis was performed on ROIs placed in cortical grey matter regions.

RESULTS

The FAIR subtraction data ΔM(τ) and fits to the theoretical model are shown in the figure below (left). It is clear that the variation of ΔM with τ is well described by a monoexponential recovery. The T_{1a} values resulting from the fits for all the animals are shown in the Table below. The average value of T_{1a} from the fits was **1.51 ± 0.11s** (mean ± SD). Also shown in the table are the corresponding brain tissue T_1 values for each mouse. The average value of brain tissue T_1 was **0.92 ± 0.04s** (mean ± SD), which is significantly less than the measured value of T_{1a} ($p<0.0001$). This demonstrates that the recovery rate of ΔM as a function of τ reflects something different from tissue T_1 and is consistent with previous measurements of arterial blood T_1.



Animal no.	ROI in cortex	
	T_{1a} (s)	Tissue T_1 (s)
1	1.58	0.90
2	1.51	0.90
3	1.47	0.88
4	1.60	0.99
5	1.40	0.92
Mean ± SD	**1.51 ± 0.11**	**0.92 ± 0.04**

DISCUSSION AND CONCLUSION

A new method for the *in vivo* measurement of arterial blood T_1 has been proposed and applied in the mouse. The method uses the tissue FAIR signal difference, and therefore does not require direct measurement of the intravascular blood signal. As a result, many of the problems associated with T_{1a} measurements are avoided. Consequently, T_{1a} can be measured directly (rather than extrapolated from literature values obtained at different field strengths), improving the reliability and accuracy of CBF quantification using ASL.

REFERENCES

(1) Pell, Thomas, Lythgoe *et al.* MRM **41**, 829-40 (1999) (2) Ordidge, Wylezinska, Hugg *et al.* MRM **36**, 562-6 (1996)