Rapid Measurement of Transit Time, CBF, M0 and T1 With Turbo-CASL

G. R. Lee[1], L. Hernandez-Garcia[1], and D. C. Noll[1]
[1]University of Michigan, Ann Arbor, MI, United States

Introduction

Quantitative measurements of cerebral blood flow (CBF) with arterial spin labeling sequences depend on the measurement of a number of parameters including the T1 of brain and arterial transit time. Other parameters involved in quantification, such as the brain-blood partition coefficient, the labeling efficiency, and the T1 of blood, are usually not explicitly measured. Turbo-ASL techniques rely on the use of a short tagging duration to increase temporal resolution and SNR [1]. Turbo-ASL approaches have been shown to be very sensitive to arterial transit time, with maximal signal occurring when TR = transit time [Fig 3. of Ref 2]. By scanning at a range of TR values to locate this signal peak, both transit time and cerebral blood flow can be measured. An added benefit is that the control images from the same data set are essentially a saturation recovery experiment that can be used to fit T1 and M0 at each voxel as well.

A number of approaches for making transit time measurements have been previously proposed. The simplest approach involves making multiple measurements with variable labeling durations or post labeling delays to observe the tag uptake [3]. However, it can take a long time to acquire the data with sufficient SNR to make a reliable measurement. A more rapid approach proposed for single-slice transit time measurements is to use a look-locker technique to sample the tag arrival at multiple times within a single TR [4].

Although the use of long post-inversion delays can reduce transit time dependence [5], this often requires a longer TR or shorter labeling duration and some residual sensitivity to transit time remains. As such, a measurement of transit time is of interest for quantification purposes. Choosing an optimal TR for fMRI applications of the Turbo-CASL technique also relies on a measurement of the resting state transit time.

Methods

Data from a human subject was acquired on a 3 T GE Signa Lx scanner in accordance with Institutional Review Board regulations. 16 Control/Tag image pairs were acquired at each of a range of TR values [0.9, 1, 1.1, 1.2, 1.3 , 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 3, 4, and 5 seconds] via the two-coil Turbo-CASL technique [2]. Tagging duration was set to TR-220ms in each case. The pulse sequence was designed to automatically step through the desired range of TR values. Scan parameters: Spin echo spiral readout, TE=21ms, FOV 24 cm, matrix size 64, 4 oblique slices (7mm thick) through the occipital cortex. Flow spoiling gradients (b=4 s/mm^2) were used. Values for T1 and M0 were fit to the control image intensities (y) at each TR using the expression: $y=M0*(1-\alpha*\exp(-TR/T1))$. The parameter α, which ranges from 0 to 1, accounts for imperfect slice profile in the excitation pulse. The fitted M0 value for CSF was used to estimate M0 for arterial blood as in Chalala et al. [6]. Transit times and CBF were fit using Eqns. 2 & 3 from Hernandez et al. [2]. All fits were performed in MATLAB using a nonlinear least squares algorithm.

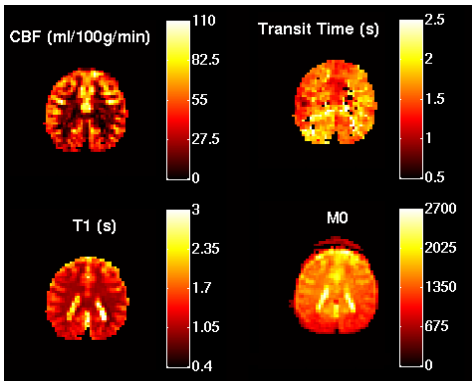

FIG. 1

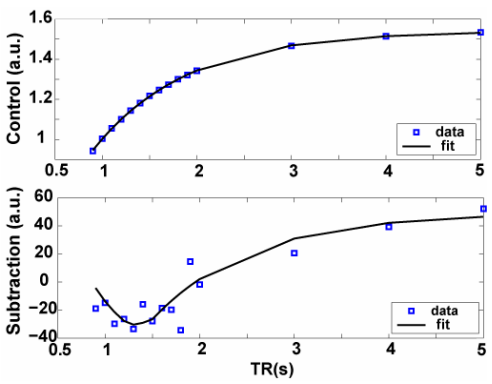

FIG. 2

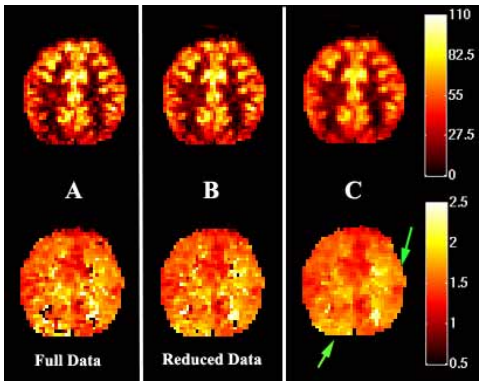

FIG. 3

Results and Discussion

Fitted values for CBF, T1, M0, and transit time are shown in FIG 2 for a representative slice. The single-voxel fits for transit time and CBF are unreliable in white matter where ASL SNR is low. A typical fit for a single gray matter voxel is show in FIG 2. Spatial smoothing of the data with a 2mm FWHM Gaussian kernel before fitting reduced the average MSE of the Turbo-CASL curve fits in the gray matter by 32.5% at the cost of increased partial volume effects (FIG 3C). All other fits displayed are from unsmoothed data. The longer transit times in the regions indicated by the green arrows relative to the contralateral side are consistent with abnormalities observed in a Time-of-Flight angiogram of the subject.

There is a noticeable gradient in the M0 image of FIG 1, with intensities becoming reduced in the bottom third of the slice. This is most likely because this portion of the oblique slice was near the inferior edge of the birdcage coil where sensitivity is reduced relative to that in the coil center. This variation in sensitivity across the slice is not accounted for when a fixed estimate for M0blood is used and will result in a scaling of the CBF flow values along the direction of the sensitivity variation. It should be noted that the measured values for CBF also depend on the assumed value of 0.8 for the inversion efficiency. Dispersion of the tag during transit can also result in reduced ASL signal at shorter TR values leading to underestimation of CBF [7].

The range of TR values used in the present work was fairly large and required approximately 15 minutes to acquire. By repeating fits to the same data, but using a reduced number of the datapoints we have determined that comparable fits to gray matter voxels are possible with significantly fewer measurements. Fits obtained with only 8 Tag/Control pairs and a reduced set of TR values [1, 1.2, 1.4, 1.6, 1.8, 2, 3, 4] are shown in Fig. 3B. This reduced data set requires less than 5 minutes to acquire.

References: 1. Wong et al. MRM 44:511 (2000) 2. Hernandez-Garcia et al. MRM 51:577 (2004) 3. Ye et al. MRM 37:226 (1997) 4. Günther et al. MRM 46:974 (2001) 5 Alsop et al, JCBFM 1236:383 (1996) 6. Chalela et al. Stroke 31:680 (2004). 7. Lee et al. Proc. ISMRM 2006 p.671

Support: NIH grant R01EB004346-01