# Dynamic Relationship Between Arterial Transit Time and Perfusion and Its Implications for Fast ASL Quantification

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## Introduction

Fast ASL techniques, such as Turbo-CASL [1,2], can be leveraged to exploit the changes in transit time that occur during activation-induced perfusion changes in order to achieve enhanced sensitivity to cerebral activation [3]. The caveat with this approach is that quantification of perfusion from the ASL signal becomes more difficult, as the relationship between cerebral blood flow (CBF) and Turbo-CASL signal changes is strongly non-linear. Recent work to quantify the Turbo-CASL signal relied on the assumption of a linear relationship between transit time changes and perfusion changes [2]. In the present work, we measured cerebral perfusion and arterial transit time (defined as the time it takes the label to arrive at the tissue) at rest and for two motor activation conditions as well as at rest and while breathing 100% oxygen. Breathing pure oxygen has been previously demonstrated to reduce global CBF [4].

## Methods

Three subjects were scanned with a 3T GE scanner using a double coil system described elsewhere [1,2] for arterial spin labeling. Four ASL slices were collected over the motor cortex using spin echo Turbo-CASL spiral sequence (resolution 64, FOV=24 cm, TE=21 ms, flow crushers: b=4 s/mm$^2$, 7 mm slices, 3 mm gap) at 14 TR values between 900 and 4000 ms. In all cases, the labeling duration was set to TR-220 ms. This series of Turbo-CASL scans was repeated for four sets of conditions: rest, a simple bi-lateral motor task (index-to thumb opposition), a complex bi-lateral motor task (sequence of all fingers to thumb opposition), and rest while breathing pure oxygen. Each of the four conditions was 13 minutes in duration to allow for 16 tag/control pairs to be acquired at each TR.

T1 values were estimated by fits of a saturation recovery curve constructed from the control image intensities at the various turbo-CASL TRs scanned. The perfusion and transit time of all voxels were estimated from the Turbo-CASL data by fitting the static kinetic model given in [1] for all four conditions. Motor cortex voxels were identified by thresholding the subtraction of the perfusion estimates of the rest case from those of the complex motor activation case. The estimated perfusion rates and transit times were converted to percentage differences from the rest case in air and then linear regression was performed to determine the proportionality constant between CBF and transit time percent changes.

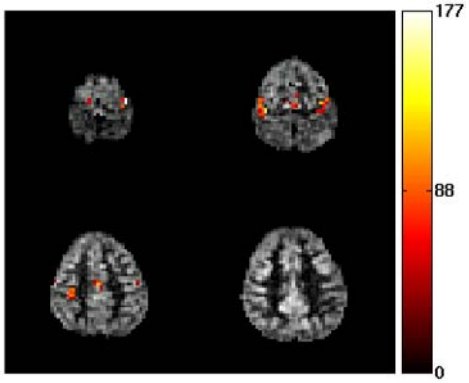


Fig. 1

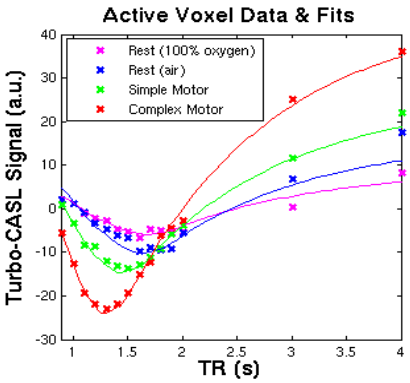


Fig. 2

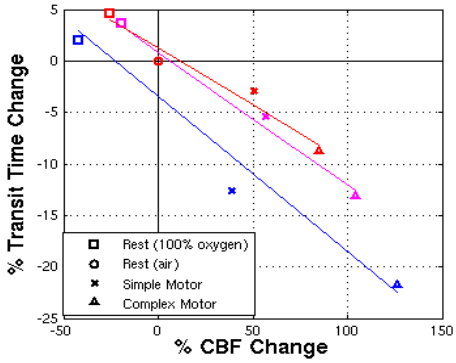


Fig. 3

## Results and Discussion

Fig. 1 shows perfusion estimate images resulting from the fit to the Turbo-CASL data in the resting case. Overlaid in color are the percentage CBF increases for each voxel considered active in the complex motor task. This set of voxels was used for all subsequent analysis. The corresponding turbo-CASL data averaged over these voxels for a representative subject is plotted in Fig. 2. The fits to this averaged data are shown as the solid lines in each case. The negative signal peak corresponds to transit time while the amplitude of the curve is proportional to perfusion [1]. As expected, the two motor tasks resulted in both an increase in signal amplitude and a decrease in transit time. A larger change occurred for the complex motor task. Breathing a pure oxygen mixture at rest resulted in a decrease in perfusion. The global gray matter CBF decrease measured for the three subjects breathing pure oxygen ranged from -16.6 to -28.0%. These are reasonable values as compared to the literature. A recent single coil CASL study by Floyd et al. [4] reported a somewhat larger gray matter CBF decrease of approximately 32%.

The transit times and perfusion values fit to the averaged active voxel data (e.g. Fig. 2) were represented as percentage changes from the resting case. These percentage changes relative to rest are plotted for all three subjects in Fig 3. It can be seen that most of the variability in the data is explained by a linear fit of similar slope for each subject. The slopes of the fit for the three subjects were -0.150, -0.129, and -0.111 with $r^2$ values of 0.935, 0.984, and 0.954 respectively. Thus, the percent reduction in transit time was roughly 10-15% of the percent increase in perfusion for these three subjects. This is moderately lower than the slope of –0.2 that was used in our previous modeling work [2]. One possible source of difference is the use of flow spoiling gradients in the current study. The large $r^2$ values of the linear fits strongly suggest that the assumption of a linear relationship is justified over the range of CBF rates studied. More subjects will be necessary to determine the degree of variability in slope among the adult population as well as the typical intrasubject variability.

## References

1. Hernandez-Garcia: Magn Reson Med, 51(3), 577-85, 2004.
2. Hernandez-Garcia: Magn Reson Med, 54(4), 955-64, 2005.
3. Lee: Proc. ISMRM, 519, 2004.
4. Floyd: J Appl Phsyiol, 95:2453-2461, 2003.

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