Investigation of the theoretical signal model used in random vessel encoded arterial spin labeling

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Purpose:

Random vessel encoded arterial spin labeling (R-VEASL) was proposed to simultaneously measure CBF and detect feeding arteries without prior knowledge of their positions [1-2]. In R-VEASL, the correlation coefficient (CC) between acquired perfusion signal data and a theoretical signal model was calculated for all possible vessel locations. The vessel location corresponding to the highest CC was assigned to each voxel. The theoretical ASL signal model was generated by Bloch simulation with a specific velocity interval of blood flow. The goals of this work are to verify the accuracy of the theoretical model used in R-VEASL, and to investigate whether the data can be used to predict the vessel velocity through this model.

Methods:

Five healthy subjects were studied in a General Electric MR750 3T scanner, using a commercial 8-channel head RF coil, under a protocol approved by the local IRB, and described in [2]. MR angiograms were acquired and were used to select two different tagging planes: one is the triangular arrangement of internal carotid and basilar arteries at the level of the sphenoid sinus; the other one is above the Circle of Willis, allowing tagging of anterior and posterior cerebral arteries, and branches of the middle cerebral artery.

The blood flow in each vessel was assumed to be laminar. In our previous R-VEASL results, the ASL model was calculated by Bloch simulation, assuming a mean velocity of 20 cm/s in the direction of the tagging gradients. A good fit to this signal model is given by:

$$\Delta Mz = 2.092\cos(\theta) - 0.322\cos(3\theta) + 0.053\cos(5\theta)$$

where θ is the phase shift between tagging pulses. The model was re-simulated for mean velocities from 10-60cm/s, and the CC between the data from the 60 encoding steps and the model was calculated. For different velocity intervals, mean CC value of voxels with CCmax > 0.8 was calculated for each perfusion territory. We hypothesize that the mean velocity with highest CC may provide an estimate of the actual blood flow velocity for each vascular source.

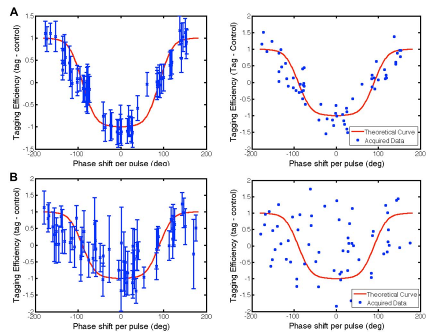

Figure 1. Data of one perfusion territory (blue) fitted with the current theoretical ASL signal curve (red) A, Good fitting result; B, Poor fitting result.

Results:

As indicated in **Fig.1**, voxel data of one perfusion territory is fit with the predicted ASL signal curve generated by the theoretical signal model. The 60 encoding steps randomly distribute across phase shift values, and the signal from each voxel distributes approximately evenly around the theoretical signal curve. In **Fig.1A**, the CC between acquired voxel data and theoretical signal has a mean value of 0.9320. However, for some other territories, the fit is significantly worse. For example, in **Fig.1B**, the CC value has a mean value 0.6764. In this perfusion territory of this subject, the supply is mixed from two sources, and the poor fit to the theoretical signal from any one source is likely related to this mixed supply.

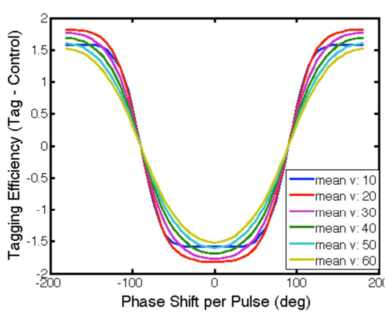

Figure 2. The theoretical ASL signal curves generated using different flow velocity.

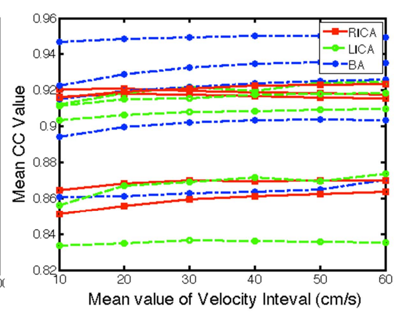

Figure 3 Mean CC of each perfusion territory for different flow velocity intervals.

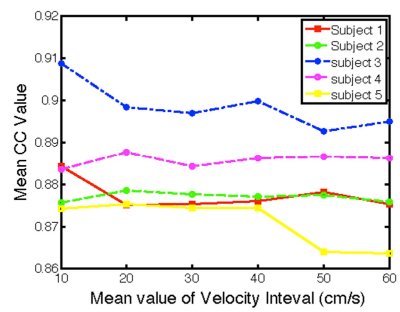

Figure 4. Mean CC value of branches of the middle cerebral artery for different flow velocity interval

For different mean velocities the theoretical signal curves are shown in **Fig.2**. For the tagging plane at the level of the sphenoid sinus, the mean CC for voxels with CC>0.8 in each perfusion territory is shown in **Fig.3**. We note that the CC has a very weak dependence on the mean velocity. When the tagging plane is selected higher, mean CC values of voxels with CC>0.8 of the branches of the middle cerebral artery is lower than that of large vessels, as shown in **Fig.4**, but again the dependence upon the assumed velocity is weak.

Conclusion and Discussion:

The theoretical signal model derived from Bloch simulation that is currently used to estimate vessel location in R-VEASL appears to generally fit the data well, and is insensitive to the assumed flow velocity across a wide range of velocities. This suggests that the method is robust to assumed velocity for the purpose of vessel detection, but also that the data likely cannot be used to estimate flow velocities.

References:

[1]Wong, EC, Guo, J, ISMRM p.294, 2011. [2]Wong, EC, Guo, J, MAGMA, 25(2):95-101, 2012.