# HIPPOCAMPUS PERFUSION STUDIES USING OPTIMAL FAIR

X. Li[1], S. N. Sarkar[2], D. E. Purdy[3], R. W. Haley[4], and R. W. Briggs[1,4]

[1]Radiology, UT Southwestern Medical Center, Dallas, TX, United States, [2]Radiology, Beth Israel Deaconess Medical Center, Boston, MA, United States, [3]Siemens Healthcare, Malvern, PA, United States, [4]Internal Medicine, UT Southwestern Medical Center, Dallas, TX, United States

## Introduction

The hippocampus plays a critical role in learning and memory (1), and has been indicated to be affected in many brain diseases (2,3). The anterior hippocampus may have different blood flow characteristics from the rest of the hippocampus because of different sources of arterial blood supply: internal carotid arteries and posterior cerebral arteries (8). Therefore, measuring perfusion in the sub-regions of the hippocampus has significant importance. To facilitate reliable perfusion measurements in the sub-regions of the hippocampus, especially to increase the sensitivity to detect small perfusion differences across patients, we developed OPTIMAL FAIR and performed comprehensive optimization studies to help the proper selection of arterial spin labeling (ASL) parameters.

## Materials and Methods

The OPTIMAL FAIR (orthogonally positioned imaging tagging method for arterial labeling with FAIR) technique keeps the imaging plane perpendicular to the feeding arteries by rotating the imaging slab relative to the other components of FAIR with Q2TIPS (4,5). This provides a more uniform transit time within the imaging slice, giving tighter and more accurate estimates of the CBF from the single-compartment model (6,7). The oblique coronal imaging slices with high in-plane resolution can also minimize partial volume effects. Optimization studies included multiple inversion, post-bolus delay, and TR effect studies.

Four healthy male adults (32 ± 7 years) participated in the three-session optimization studies on a 3T Siemens TIM Trio whole body scanner. The body coil was used for RF transmission and the Siemens 12-channel phased array receive-only head coil for imaging. All subjects were screened and provided written informed consent according to a study protocol approved by the Institutional Review Board.

All optimization studies used the following parameters: TE = 14 ms, FOV = 128 x 128 mm, matrix size = 64 x 64, slice thickness/slice gap = 8/1.6 mm, 6 imaging slices, in-plane resolution = 2.0 x 2.0 $mm^2$, left to right phase-encoding direction with 20% phase oversampling, 6/8 partial Fourier encoding, 148 mm selective inversion slab, 328 mm spatially-confined inversion slab, 110 measurements, iPAT GRAPPA factor = 2. The multiple inversion study used TR = 4.0 s, randomized inversion times ranging from 300 to 2700 ms in 300 ms increments and the inferior saturation pulse train off. Parameters for the post-bolus delay optimization study were TR = 3 s, temporal bolus width ($TI_1$) = 600 ms, post-bolus delay times of 0.4, 0.8, 1, 1.2, 1.4, and 1.8 s, the maximal number of inferior saturation pulses that fits each post-bolus delay; and inferior saturation slab size/pulse interval = 20 mm/25 ms. The TR effect study used four TR values (2.5, 3, 3.5, and 4 s), 0.6 s bolus width, 1.2 s post-bolus delay, and 40 inferior saturation pulses. Two $M_0$ images were acquired using the same sequence with TR = 8 s for quantitative CBF evaluation.

Hippocampus ROIs were obtained from MPRAGE $T_1$-weighted high resolution anatomic images using the FIRST tool of FSL and co-registered to each ASL series using SPM software. Four-parameter iterative non-linear least squares model fitting was performed in Matlab. CBF quantification used a single blood compartment model (6, 7). The hippocampus was manually segmented into three sections with the anterior segment covering the hippocampus head and the other two segments evenly covering the rest of the hippocampus.

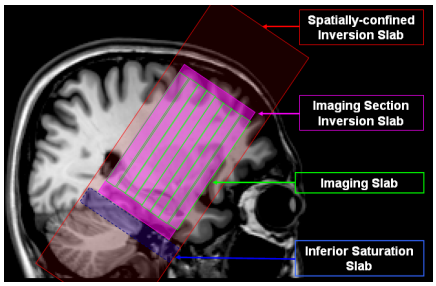


**Fig. 1** Spatial definitions of different slabs in OPTIMAL FAIR.

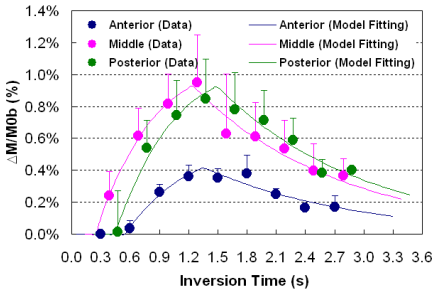


**Fig. 2** Group mean hippocampus perfusion signal changes with inversion time and corresponding model fitting curves for the three segments.

**Table 1 Estimated Parameters (mean ± SD) from Multiple Inversion Experiments and P Values from Two-tailed and Paired T-tests (N=4)**

| Estimated Parameter | Ant. | Mid. | Pos. |
|---|---|---|---|
| Arterial Transit Time (ms) | 545.6 ± 53.1 | 316.6 ± 85.9 | 443.4 ± 15.1 |
| CBF (mL/100g/min) | 38.6 ± 7.9 | 68.5 ± 11.4 | 70.6 ± 15.7 |
| Bolus Duration (ms) | 818.2 ± 132.1 | 883.4 ± 174.5 | 782.7 ± 203.5 |
| $M_{0Blood}$ (a.u.) | 1498.2 ± 0.8 | 1500.8 ± 0.6 | 1500.6 ± 1.0 |
| **P Values from Performed Comparisons** | | | |
| **Compared Parameter** | **Ant. vs Mid.** | **Mid. vs Pos.** | **Ant. Pos.** |
| Arterial Transit Time | **0.011** | **0.044** | **0.040** |
| CBF | **0.002** | 0.828 | **0.022** |
| Bolus Duration | 0.634 | 0.264 | 0.807 |
| $M_{0Blood}$ | **0.007** | 0.732 | **0.038** |

Note: Ant., Mid. and Pos. represent anterior, middle and posterior segments respectively. Significances (p<0.05) were highlighted using bold font.

## Results and Discussion

The anterior segment of the hippocampus has the lowest perfusion and the longest transit time (Fig. 2 and Table 1). The different blood flow dynamic characteristics between the anterior and the other parts of the hippocampus may be because the blood supply for the anterior segment is different from that for the middle and posterior parts of the hippocampus; the blood supply from the carotid arteries goes up and then curves back to the hippocampus head (8). To avoid hyperintensive signals within big blood vessels, a transit time longer than 0.8 s should be used for subsequent quantitative hippocampus perfusion studies (Fig. 3). Although there is some overlap of the labeling and imaging slabs due to their relative positions, the use of oblique coronal imaging slices avoided undesired saturation of the proximal arterial blood due to imaging slice acquisition (Fig. 4 ).

## Acknowledgements

This study was supported by DoD grant DAMD 17-01-1-0741 and VA IDIQ contract VA549-P-0027. The content of this abstract does not necessarily reflect the position or the policy of the U.S. government or the sponsoring agencies, and no official endorsement should be inferred.

## References

1. Eichenbaum H, Memory, Amnesia, and the Hippocampal System: MIT Press; 1993. 2. Becker et al. Arch Neurol 2006;63(1): 97-101; 3. Jack et al. Neurology 2000;55(4): 484-489. 4. Kim et al. MRM 1995; 34(3): 293-301. 5. Luh et al. MRM 1999. 41(6): 1246-54. 6. Buxton et al. JMRI 2005;22(6): 723-726. 7. Parkes. JMRI 2005; 22(6): 732-6. 8. Duvernoy HM. The Human Hippocampus Functional Anatomy, Vascularization and Serial Sections with MRI. Springer-Verlag Berlin Heideiberg New York 2005;Third Edition.

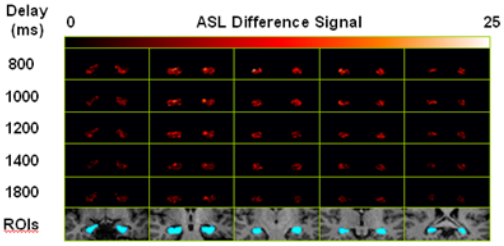


**Fig. 3** Hippocampus perfusion signal changes with post-bolus delay times and hippocampus ROIs overlaid on co-registered anatomic images.

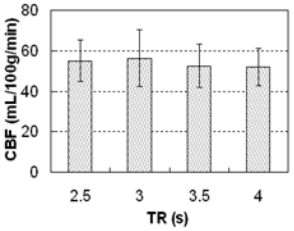


**Fig. 4** Hippocampus CBF measurements using different TR values.