Localization of the hand motor area using BOLD and ASL fMRI

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Introduction:
Functional magnetic resonance imaging (fMRI) techniques can be useful in the pre-surgical mapping of eloquent brain tissue. Previous studies have shown that perfusion-based Arterial Spin Labeling (ASL) methods produce results with better spatial specificity than the most commonly used Blood Oxygen Level Dependent (BOLD) contrast [1]. These studies have focused on the relative location of the activation areas with regard to proximal draining veins, showing a bias for the BOLD signal to be shifted towards the venous compartment relative to the ASL contrast. In this study, we aimed to compare the localization of the hand motor area obtained by simultaneous ASL-BOLD fMRI and standard BOLD fMRI with well established anatomical landmarks [2].

Methods:
Fifteen healthy volunteers were studied on a Siemens Verio 3T system using a 32-channel head coil. The fMRI sessions included two functional experiments, using a standard BOLD protocol and a simultaneous ASL-BOLD protocol, where the subject performed a sequential thumb-digit apposition task. A pulsed ASL Q2TIPS-PICORE sequence with a GE-EPI readout was used for the ASL-BOLD fMRI acquisition, with TR/TE=2500ms/11ms and $TI_1/TI_{1s}/TI_2$ =700ms/1600ms/1800 ms, 9 contiguous axial slices 6 mm thick, positioned parallel to the AC-PC line, with an in-plane resolution 3.5x3.5mm^2. A FOCI 180° inversion pulse was applied to a 10cm thick labelling region, positioned 18.8mm below the proximal imaging slice. Between and , saturation pulses were repeatedly applied over a 20mm thick saturation slab. The fMRI paradigm employed a blocked design consisting of 5 cycles of rest and task periods of 25sec duration each. A total of 101 volumes alternating between tag and control were acquired, resulting in a total acquisition of 4min 12.5sec. The BOLD fMRI acquisition used a GE-EPI readout with TR/TE = 3000ms/30 ms. The BOLD-fMRI protocol used a block design consisting of 4 cycles of rest and task periods of 30sec each, resulting in a total acquisition of 4min.
The fMRI data were analyzed with a standard General Linear Model (GLM) approach using FEAT from FSL (www.fmrib.ox.uk/fsl). Image pre-processing included motion correction, spatial smoothing with a 5 mm Gaussian kernel and high-pass temporal filtering with a 100 ms frequency cutoff. For the BOLD data, the motor task periods were convolved with a gamma function HRF and its first temporal derivative and contrasts between task and rest were then performed to produce activation clusters, using a cluster thresholding procedure with voxel Z>2.5 and cluster p<0.05. For the ASL-BOLD data, an additional explanatory variable was defined to describe the alternation between tag and control volumes and the interaction between this and the motor task variables was then considered for the analysis of the perfusion-based activation.
A number of anatomical landmark points were defined on the hand primary motor cortex (HMC) in the MNI standard brain, as shown in Figure 1. The activation clusters given by each experiment (BOLD, $BOLD_{ASL}$ and ASL) of each subject were registered to the MNI standard brain using FLIRT from FSL and the Euclidean distance between each cluster's centre of gravity (COG) and the HMC was then computed.

Results:

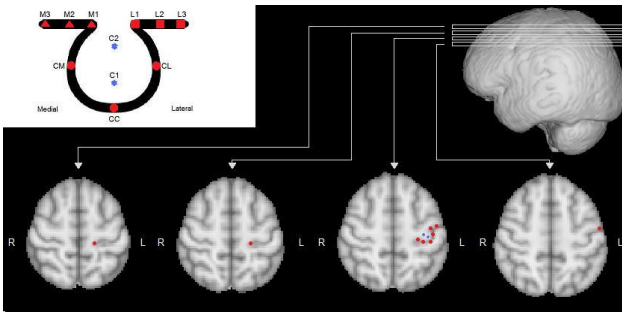

Figure 1: Localization of the HMC: 9 points over the segment of the precentral gyrus (in red) and two calculated mean points (in blue), defined over 4 axial slices in the MNI standard space.

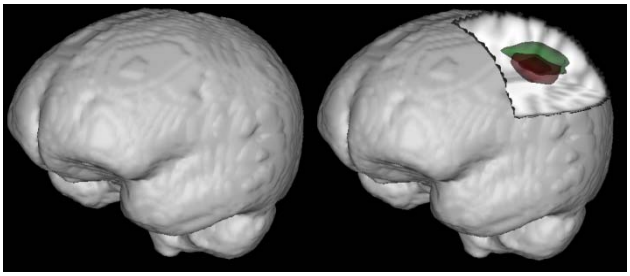

Figure 3: Inter-subject variability of BOLD (red), $BOLD_{ASL}$ (green) and ASL (blue) activation clusters: cluster COGs and local maxima are shown for all subjects to illustrate the area of overlap.

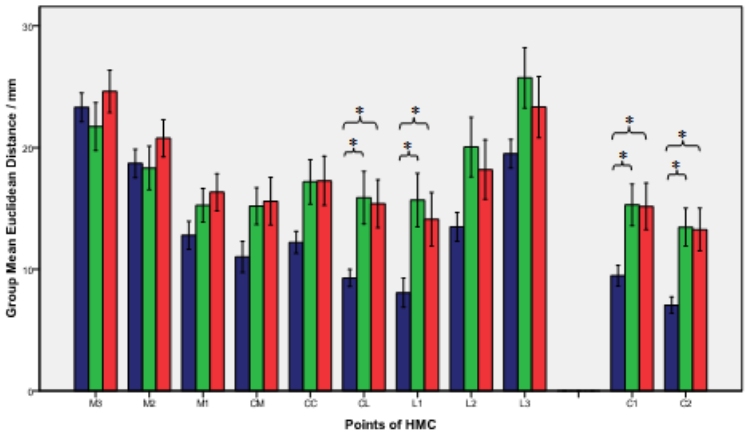

Figure 2. Group mean Euclidean distance (mm) from the HMC points to the activation COGs obtained using ASL (blue), $BOLD_{ASL}$ (green) and BOLD (blue). Error bars denote one standard error of the group mean. * denotes significant differences.

ANOVA revealed significant differences in the distances between BOLD, $BOLD_{ASL}$, and ASL COGs with respect to CL ($p<0.017$), L1 ($p<0.019$), C1 ($p<0.017$) and C2 ($p<0.009$). The post-hoc multi comparison of the mean distance values according to Scheffe revealed significant differences between the following distances: ASL and $BOLD_{ASL}$ COG to CL ($p<0.036$), ASL and $BOLD_{ASL}$ COG to L1 ($p<0.027$), ASL and BOLD ($p<0.041$) and $BOLD_{ASL}$ ($p<0.046$) COGs to C1, and ASL and BOLD ($p<0.010$) and $BOLD_{ASL}$ ($p<0.013$) COGs to C2. The variance values across subjects of the COG coordinates (x,y,z) in mm^2 for ASL activation (9.5, 28.3, 6.0) were smaller than the variance values for $BOLD_{ASL}$ (78.4, 92.6, 38.0) and BOLD (73.1, 106.4, 16.8).

Conclusion:
Our results indicate that the localization of the hand motor area obtained using ASL fMRI was less variable and closer to the HMC anatomical landmarks than the one produced by both simultaneous $BOLD_{ASL}$ and standard BOLD fMRI. This supports the notion that ASL may more accurately localize brain activation than BOLD.

References:
[1] Tjandra, T., et al., NeuroImage, 2005. 27(2):393-401.
[2] Yousry, T.A., et al., Brain, 1997. 120: p. 141.

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