CBF Changes During Brain Activation: fMRI vs. PET

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Introduction

Positron emission tomography (PET) and magnetic resonance image (MRI) have been developed to be practical tools to measure cerebral blood flow (CBF) *in vivo*. PET technique has been validated with the standard tracer technique (Raichle et al., 1983) and is considered to be the "gold standard" in CBF measurements in humans. With advantages such as providing higher spatial resolution and repeatability, MRI is gaining popularity in generating CBF maps.

Two distinct MRI methods are currently used in obtaining CBF images: contrast-agent dynamical perfusion, and arterial spin labeling (ASL) techniques. These two MRI methods have been compared with the PET technique in determining CBF values at resting state for both healthy volunteers and patients (Østergaard et al., 1998). Their previous results have showed that, at resting state, CBF values measured by MRI were not statistically different from the values measured by PET.

CBF-based PET and fMRI techniques have been used in brain activation studies. Due to its simplicity and cost-efficiency, ASL-based MRI technique has played a dominated role in fMRI field as compared to the contrast-agent dynamic perfusion MRI method. Although the resting-state CBF images obtained by both PET and MRI were compared in previous studies as mentioned above, no single study has compared the CBF brain activation maps generated by PET and fMRI techniques. By using an activation study under precisely controlled conditions in a single group of subjects and using identical visual stimuli, we have compared quantitatively, the functional CBF maps obtained by PET and ASL-based fMRI.

Material and Method

Experiments were performed using a whole body 1.9 T GE/Elscint Prestige MRI scanner and a Siemens/CTI-HR+ whole body PET scanner. Twelve healthy subjects participated in this study. An identical full field circular checkerboard, flashing at 8 Hz, was presented as the visual stimulus for both PET and fMRI experiments. In the resting state, a cross hair was presented as fixation control during the functional studies.

An inversion recovery spin-echo single-shot echo-planar imaging (EPI) sequence and a flow-sensitive alternating inversion recovery (FAIR) technique were used for CBF based imaging. A single slice of an oblique plane containing the calcarine fissure was imaged. The image parameters of the pulse sequence were as follows: slice thickness = 7 mm, in plane spatial resolution = 3.0 mm x 3.0 mm, TR/TE/θ = 2000 ms/37 ms/90^o, and TI = 1000 ms. CBF-based images was obtained by subtracting the slice-nonselective images from the slice-selective images after a correction for the BOLD effect induced by the EPI acquisition was made (Kim, 1995).

All subjects underwent a single PET scan session consisting of 4 CBF scans in two separate blocks – resting (control) and activation (visual stimulation) states. Emission PET scans were performed following an intravenous bolus injection of 50 mCi of $H_2{}^{15}O$ contained in 12 ml of saline. The PET scan is reconstructed and decay-corrected (Mintun et al., 1984).

Summed PET images from each scan were spatially registered and resliced to match the high resolution T_1-weighted MR image. Regions of interest (ROIs) were determined anatomically on the high resolution T_1-weighted image and were then applied to all PET images for statistical analysis. Images acquired during activation state was compared with those from resting state using an unpaired Student's t-test to determine the voxels with statistically significant ($p < 0.05$) activation. A conjunct region of interest (ROI) was determined by choosing the pixels ($p < 0.05$) activated both on the PET and MRI activation maps in the visual cortex areas. Percentage CBF changes were calculated based on the values within the conjunct ROI for both PET and fMRI images.

Results

fMRI and PET maps of rCBF change during visual stimulation, averaged throughout 10 subjects is shown in Figure 1 (fMRI-left; PET-right). A highly focal statistically significant activation ($p < 0.05$), due to relative CBF change, can be seen in the visual cortex.

CBF comparisons with the conjunct ROI showed that the relative average CBF changes in fMRI is 36.95 ± 2.54 % while in PET is 38.79 ± 2.63 % (Figure 2(a)). There was no statistically significant difference between fMRI and PET measurements in determining the relative changes of CBF response visual stimulation ($p = 0.22$).

Number of pixels that exceeded the significance level ($p < 0.05$) in visual cortex was measured to be 611 ± 140 pixels in fMRI and 607 ± 123 pixels in PET and is shown in Figure 2 (b). There was no statistically significant difference between PET and fMRI methods in determining the functional CBF maps ($p = 0.49$).

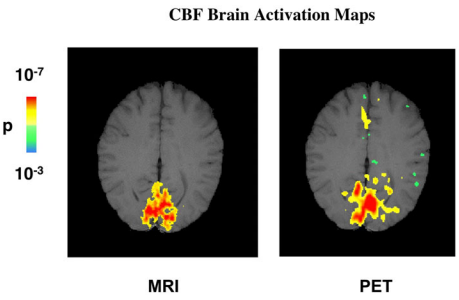

Figure 1

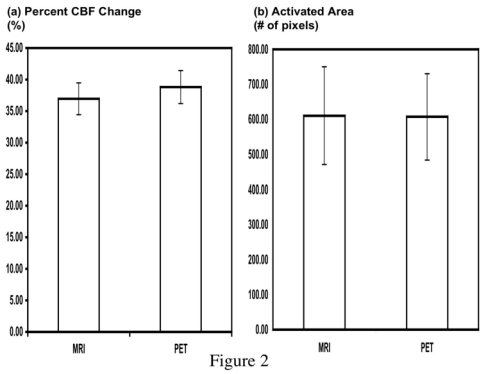

Figure 2

Discussions and Conclusions

A direct comparison study of the relative changes in CBF response to visual stimulation measured by fMRI and PET was performed. The results have demonstrated that there is a reasonable agreement in the functional CBF maps generated by MRI and PET techniques. Both the percentage change of CBF, and extent of activation area using two image modalities were examined, and their values agree well with each other. No statistically significant difference was found between MRI and PET in the assessment of functional CBF maps.

This report, for the first time, has demonstrated that the CBF-based brain activation maps generated by PET and fMRI have a high degree of similarity. No significant difference was detected for using these two neuroimaging methods in determining the activation areas, as well as the percentage changes of CBF.

References

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