In the past decade, the most significant development in MRI is the introduction of fMRI, which permits the mapping of human brain function with exquisite details non-invasively. Functional mapping can be achieved by measuring changes in the blood oxygenation level (i.e. the BOLD contrast) or cerebral blood flow.

FMRI can be improved by an increase in magnetic field because both the SNR and BOLD contrast increases with the magnetic field. More importantly, theoretical considerations and experimental work suggest that the specificity, sensitivity and contrast of the BOLD response to neural activity increase with the field strength. With the establishment of a 7 Tesla whole body system in our laboratory, we have conducted fMRI experiments in humans for the first time at a magnetic field strength that significantly exceeds 4 Tesla. Functional mapping using echo-planar imaging was carried out to characterize the BOLD contrast at 7 Tesla and to explore the limits of fMRI at 7 Tesla. In addition, with the high SNR, we are able to obtain high-resolution perfusion experiments for mapping brain function. This talk summarizes these experiments and their results.

The first experiment was conducted in a group of subjects at both 7 Tesla and 4 Telsa[1]. Functional MRI data were collected with multiple TEs using a T*2-weighted echo-planar imaging sequence. Experimental data revealed that fMRI with EPI could be robustly performed at 7 Tesla. In addition, activation induced R*2 change in gray matter increased by more than a factor of 2 when going from 4 Tesla to 7 Tesla, while that in a vascular region did not change substantially. This study established that ultrahigh field MR systems are advantageous for fMRI.

Previous fMRI studies have reported an initial decrease (i.e., the initial dip) in the BOLD signal, which is believed to arise from an elevation in oxygen consumption and to be mostly microvascular. To date, experimental studies of the initial dip in humans have been performed at fields up to 4 Tesla, with relatively low spatial resolution. In a study at 7 Tesla with high spatial resolution, the initial dip was found to reside mostly in the gray matter and its amplitude relative to the late response was found to be 0.6, significantly higher than that at 4 T (0.3) and 1.5 T (0.11). In addition, assuming that the initial dip is a result of increased oxygen utilization, the change in oxygen utilization was estimated to be 40% of that of the cerebral blood flow.

T2-weighted fMRI is desirable because they are more specific to the microvasculature. BOLD T2-contrast is expected to be more prominent at 7 Tesla. To demonstrate this point, high resolution functional maps were obtained with T2-weighted EPI.
Experimental obtained activation patterns are localized to the gray matter. Consistent with dynamic averaging, the signal change was found to depend on the cube of TE. Compared with results obtained at 4 T, signal change in T2-weighted images at 7 T increased with the field strength linearly. In addition, the BOLD contrast was found to increase significantly with spatial resolution, suggesting that the partial voluming effect is significant.

Taking advantage of the increased SNR, high resolution CBF based functional mapping was also performed. These studies revealed that robust contrast can be obtained and a reduction in voxel size significantly improved the contrast because of reduced partial voluming effect.

In summary, experimental data obtained so far show that functional brain mapping at 7 Tesla can be robustly performed and that the ultrahigh magnetic field provides an increase in both sensitivity and specificity.

References:

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