The use of high spatial and spectral resolution Fourier component difference images to detect BOLD response in mouse tumors

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Introduction: BOLD MRI is often used to evaluate effects of oxygenating agents in tumors. A gradient echo with long TE or a train of several gradient echoes is often used to detect changes in T_2* reflecting changes in blood oxygenation. However, this approach leads to artifacts and loss of sensitivity when the water resonance does not behave as a homogeneously broadened Lorentzian line. The water resonance from small voxels *in vivo* is usually inhomogeneously broadened, and the various components of the water resonance often respond differently to changes in oxygenation. Here we demonstrate that with high resolution EPSI, changes in each individual Fourier component of the water resonance during carbogen breathing can be imaged. Further, we show that examination of these Fourier component images reveal BOLD changes that are missed by conventional imaging.

Method: Nude mice (n = 5) were inoculated in the hind leg with AT6.1 tumor cells. EPSI was performed using a 4.7T scanner with 195x195μm^2 in-plane resolution, slice thickness of 400µm, and ~7.8 Hz spectral resolution (TR = ~ 1.5 second, spatial/spectral matrix = 128x128x64). Data were acquired during a control period (5-10 images) and during carbogen breathing (18-21 images) with time resolution of ~3 minutes. Scans were both respiratory and cardiac gated. Three-dimensional EPSI data were Fourier transformed along the k-space and temporal (FID) axes to produce detailed water spectra associated with each small image voxel. Spectra were phase corrected to produce a pure absorption water peak in each small voxel & then shifted so that the water peak was at the same frequency bin in all voxels. An average of the control data was subtracted from carbogen data to produce FCDI's.

Results: Figure 1 shows representative data from the hind limb of tumor bearing rodents. The 'red images' show five FCDIs with positive changes; the 'blue' images display negative changes for the same Fourier components. Neighboring images in each row are separated by a frequency difference of 7.8Hz and the center image in each row is the water peak component. In both rows, white represents the greatest absolute spectral difference. We observed similar FCDIs in the other four experiments. The data suggest the following general conclusions:

1. Increases in the water spectrum during carbogen often occur almost exclusively in the central component of the water resonance, with no corresponding changes, either increases or decreases, in the off-peak images. A Lorentzian change in linewidth would result in corresponding negative changes symmetrically about the peak of the positive changes in the water resonance. Such a change occurred in very few voxels.

2. Changes, both positive and negative, are seen in small regions of the off-resonance images with no corresponding changes in the central component. Such complicated changes in the water peak may be associated with blood vessels, where the magnetic susceptibility of deoxyhemoglobin produces significant shifts in the water signal

3. Several linear structures that appear to be blood vessels are seen more clearly in the off-resonance than in the central FCDI. This could be because such features may be obscured by changes in the central component.

Discussion: Fourier component images demonstrate characteristics of BOLD contrast changes that are not detectable in conventional images. FCDI's allow isolation of the portion of the water peak where the largest changes in the Fourier components occur – while conventional images show a superposition of the changes in all of the Fourier components. Thus Fourier component images may increase sensitivity to BOLD contrast changes.

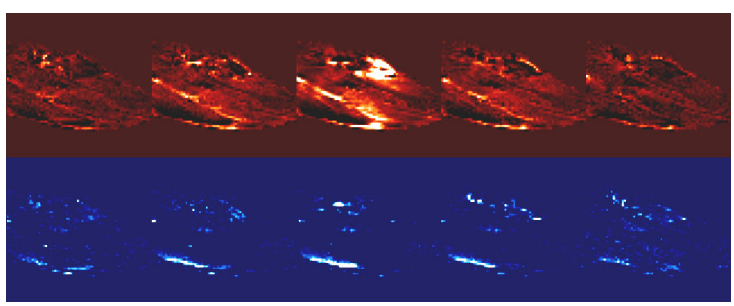

Figure 1

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