Water resonance structure obtained in high spectral and spatial resonance MRI of human breast lesions reveals two predominant components

M. Medved[1], G. M. Newstead[1], H. Abe[1], G. S. Karczmar[1]
[1]Department of Radiology, The University of Chicago, Chicago, Illinois, United States

Introduction: Studies of water resonance in small tissue voxels show that it is often inhomogeneously broadened, and sometimes contains multiple resolved components, arguably corresponding to sub-voxelar, perhaps microscopic environments (e.g. vasculature). (1-3) These environments often cannot be resolved by conventional imaging, but previous work demonstrated that the water resonance components can be identified in high spectral and spatial resolution (HiSS) images. (3) Here we show that the water resonance can be accurately modeled with a two-component Lorentzian function.

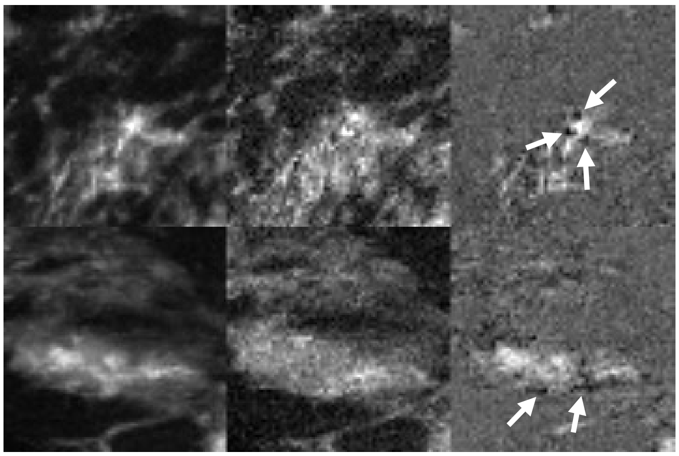

Figure 1: FCIs at 0 Hz (left), +10.4 Hz (middle), and their difference (right column) are shown for a ductal carcinoma *in situ* (top) and high-grade invasive ductal carcinoma (bottom) lesion. Dark structures (arrows) are features in off-resonance FCI not present in 0 Hz FCI.

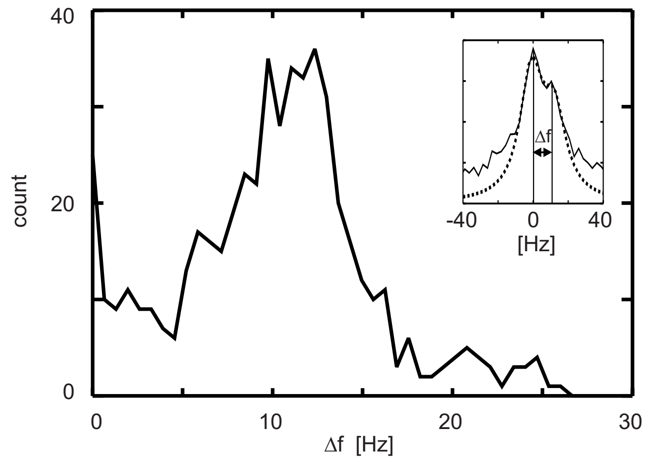

Figure 2: The histogram of Δf, the separation of two Lorentzian components of the water line fit, is shown for voxels within the lesion depicted in lower row of Figure 1. Inset: a typical voxel water spectrum that clearly shows two components, and the fit to two-component Lorentzian function.

Methods: Single-slice, sagittal HiSS images (0.65 mm x 0.65 mm x 2.6 Hz resolution, 4 mm thick) were acquired using echo-planar spectroscopic imaging (EPSI) (4) on a 1.5 T GE SIGNA^{TM} scanner, in 12 women with suspicious breast lesions. Fat and baseline signal were removed in post-processing, using Lorentzian functional form fitting. The highest intensity spectral bin in the remaining water resonance was identified and assigned "zero" frequency. Fourier component images (FCIs) were generated proportional to the signal at this nominal zero frequency and at various frequency offsets, and scaled to same average intensity to reveal differences in inherent contrast. In voxels with water peak signal > 20x the standard deviation of the noise, the water resonance was modeled by two Lorentzian lines, separated by Δf.

Results: In 7 of 12 women imaged, FCIs at various offsets show different inherent contrast, best illustrated by difference images (Fig. 1) The histogram of Δf (Fig. 2) is obtained by fitting the water resonance in voxels within a high-grade invasive ductal carcinoma lesion to two Lorentzian lines. The well-defined peak at 11 Hz (≈ 4 spectral bins) in this histogram points to two predominant components of water resonance with a separation that is consistent across the lesion. The smaller peak at 0 Hz corresponds to narrow water lines, best modeled by a single Lorentzian. This is in agreement with our qualitative observation that distinct contrast features found at the same spatial location are most often separated by four spectral bins.

Conclusion: The differences in contrast between FCIs give evidence of inhomogenous broadening of the water lines due to distinct populations of water molecules in different sub-voxelar compartments. The possibility of imaging, e.g. dense vasculature in tumors, or areas of angiogenic activity, may have great clinical utility. It is plausible that the consistent grouping of off-resonance signal around 11 Hz offset from peak signal frequency, revealed in FCI difference images and in the histogram of Δf, arises from underlying biology. Therefore, a two-component Lorentzian model of the water resonance in HiSS imaging may be useful.

References:

1. Brindle, KM et al, *Biochem J*, **180**:37-44,1979.
2. Zhong, K et al, *NMR Biomed*, **13**:392-397, 2000.
3. Medved, M et al, *Magn Reson Med*, **52**:193-196, 2004.
4. Mansfield, P, *Magn Reson Med*, **1**:370-386, 1984.