APT and NOE Imaging Contrasts of Glioma with Different RF Saturation Powers

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Target Audience: Scientists and clinicians who are interested in the development and applications of CEST and APT imaging.

Purpose

Amide proton transfer (APT) imaging[1] and nuclear Overhauser enhancement (NOE) imaging[2-3] are two potentially important molecular MRI methods for the detection of low-concentration chemicals in tissue, and are usually acquired using a pulse sequence that is similar to standard magnetization transfer (MT) experiments. When MT asymmetry analysis is used for image processing, these two effects can be entangled together.[4,5] The purpose of this abstract is to investigate these effects in rat glioma models at different saturation powers at 4.7T.

Methods

Eight 9L tumor-bearing rats were imaged on a 4.7T animal MRI scanner, with a 4 cm I.D. volume coil for RF transmission and reception (TR = 10 s; RF saturation time = 4 s; saturation power = 0.1, 0.6, 1.3, 2.1, 3.2, and 4.4 μT). Z-spectra were acquired over an offset range of ±6 ppm with a resolution of 0.5 ppm [intensity S_{sat}(offset)]. A control image in the absence of RF saturation (S_0) was also acquired for imaging intensity normalization. One image was acquired per offset (one dummy scan). B_0 inhomogeneity was corrected using a 12th-order polynomial on a voxel-by-voxel basis The MT-ratio asymmetry with respect to the water signal was defined as: MTR_{asym}(+offset) = MTR(+offset) - MTR(-offset) = [S_{sat}(-offset) - S_{sat}(+offset)]/S_0. For APT imaging, MTR_{asym}(3.5ppm) = APT - NOE(-3.5ppm).

Results

Fig. 1 shows z-spectra and MTR_{asym} spectra of tumor and contralateral normal brain tissue at three RF saturation powers. At lower saturation power levels (0.6 μT), both downfield APT (at roughly 3.5ppm from water) and upfield NOE (at -3~-5ppm from water) effects were clearly observed (Fig. 1a, b). The large NOE effect, particularly in the contralateral normal brain tissue, causes large negative MTR_{asym} values at >3ppm. The CEST signal related to side-chain amine protons (at approximately 2ppm) was also observed. When comparing the downfield z-spectra and reflected upfield z-spectra, the APT signals were smaller at 0.6 μT (Fig. 1a), but became larger at 2.1 μT (Fig. 1e) than the NOE signal in both tissue types. Fig. 2 plots the dependence of MTR_{asym} and tumor/contralateral brain tissue contrasts at offsets of 2, 3.5, and 5ppm on RF saturation powers. The maximal MTR_{asym} contrast was observed at the offset of 3.5ppm for all saturation power levels.

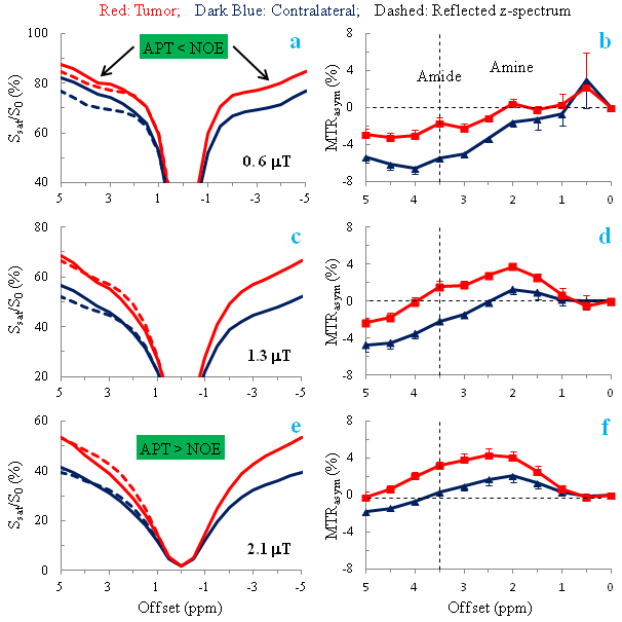

Fig. 1. Average z-spectra and MTR_{asym} spectra of brain tumor and contralateral normal brain tissue (n = 8). Note: The downfield z-spectra are higher at 0.6 μT (a) and lower at 2.1 μT (e) than the corresponding reflected upfield z-spectra.

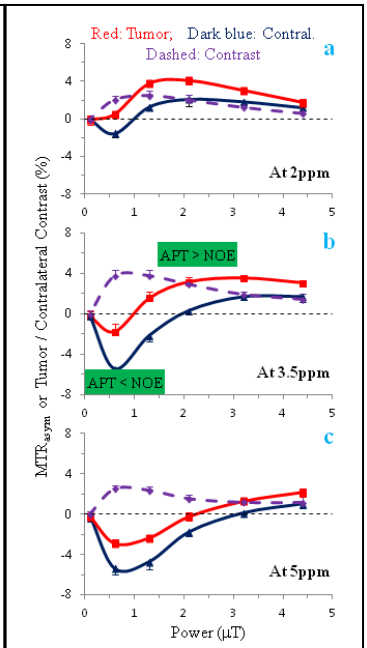

Fig. 2. MTR_{asym} and contrasts as a function of saturation power levels. The measured contrast is highest at 3.5ppm (b).

Discussion

The absolute APT-MRI signal quantified by MTR_{asym}(3.5ppm) reduces by the NOE effect. However, the APT image contrast between tumor and contralateral brain tissue increases due to the NOE effect (which is smaller in tumor than in contralateral, an image contract opposite to APT). This increase contrast is more significant at lower saturation power levels, at which the NOE effect is larger. Unlike the APT effect, this increased component may not be associated with the tumor. A slightly higher saturation power should be used for APT imaging purpose. Notably, at a saturation power of 2 μT, the measured MTR_{asym}(3.5ppm) signal was almost zero (APT = NOE) in the normal brain tissue. It has been demonstrated previously[6] that this power caused an optimal hyperintense APT-MRI signal in the tumor.

Conclusion

The NOE effect is clearly visible at lower saturation powers and is larger in contralateral normal brain tissue than in tumor; however, the APT effect is maximized at relatively higher saturation powers and is larger in tumor. These findings are important to design experimental protocols, identify the source of the APT and NOE effects, and quantify the APT imaging contrast in brain tumor.

References

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