MAGIC Polymer Gel Dosimetry Using R_1, $R_{1\rho}$, R_2, and MTC at Several Magnetic Field Strengths

J. Luci[1], D. Gochberg[1], M. Lepage[1], J. Joers[1], H. Zeng[1], T-T. Chang[1], J. Gore[1]
[1]Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States

Introduction

MAGIC (**M**ethacrylic and **A**scorbic acids in **G**elatin **I**nitiated by **C**opper) polymer gel dosimeters have several distinct advantages over dosimeters based on other formulations. They have a greater dose response slope and dynamic range and can be prepared in normal room atmosphere (1). In order to compare the ability of several NMR properties of MAGIC gels to measure dose as well as the errors and problems associated with the acquisition and analysis of the associated data, it is necessary to evaluate the efficacy of each viable parameter. We present here the dose response of R_1, $R_{1\rho}$, and R_2, of MAGIC gels at four magnetic field strengths. In addition, preliminary data show that response of Magnetization Transfer Contrast (MTC) is linear over a dose range similar to the relaxation-based measurements.

Experimental

MAGIC gels were prepared according to published procedures (1) with the only modification being the exclusion of hydroquinone, and irradiated up to 40 Gy with a Philips clinical linear accelerator. The gels were then imaged at 0.5, 1.5, 2.0, 3.0, and 7.0 Teslas (2) with standard pulse sequences (R_1: inversion recovery, saturation recovery; $R_{1\rho}$: spinlock preparation with spin echo and fast spin echo readouts; R_2: spin echo and multiple (CPMG-type) spin echo; MTC: 60 10kHz off-resonance saturation pulses (3) with interleaved spoiling gradients followed by spin echo readouts at 2.0T. Relaxation data were fit with standard 3-parameter non-linear least squares routines in Matlab, and subsequently plotted vs. dose. All the dose responses were assumed to be linear over the dose range used, and the slopes reported are from the straight line fits to these plots. MTC images were calculated using the definition of MTC, $(M_0–M_{sat})/M_{sat}$ (where M_0 and M_{sat} represent the images with and without preceding saturation pulses), are also plotted against dose.

Results

Representative data of the response in relaxivity vs. dose at 3T are shown in Figure 1. The slopes of the straight line fits through these data are plotted in Figure 2 for several magnetic field strengths (lines connecting data points are included only to aid the eye). While the slope of R_1 vs. dose is relatively insensitive to magnetic field, there is a significant advantage to moving to higher magnetic field (>1.5T) for both $R_{1\rho}$ and R_2. Figure 3 demonstrates that the slope of the MTC response changes with increasing B_1. This effect shows significant promise since the method offers good control over contrast-to-noise and the MR measurements can be made much more rapidly.

Figure 1

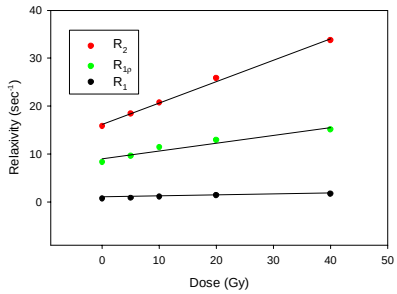


Figure 2

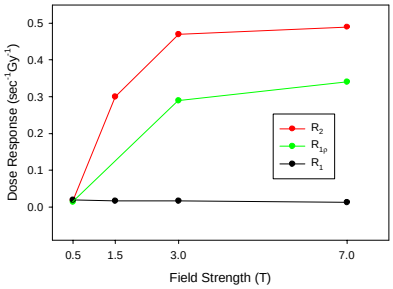
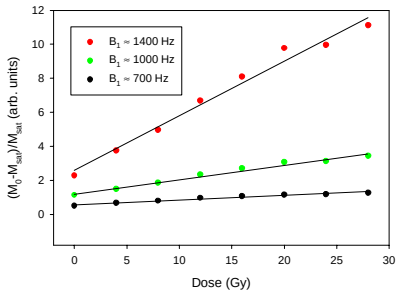


Figure 3



Conclusions

It is clear that of the relaxivity-based measurements, R_2 is most sensitive to dose, and the effect is accentuated at higher field strengths. Additionally, the MTC data suggest the possibility of finely tuning the dose response with the power of the saturation pulses.

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[1] Fong, Peter M.; Keil, Derek C.; Does, Mark D.; Gore, John C. Polymer gels for magnetic resonance imaging of radiation dose distributions at normal room atmosphere. Physics in Medicine & Biology (2001), 46(12), 3105-3113.
[2] $R_{1\rho}$ was measured at 0.5, 3.0, and 7.0 T; MTC was only measured at 2 T.
[3] B_1 field strength of spinlock used at 0.5 and 1.5T was approximately 500 Hz, and approximately 600 Hz at 7T.