A Dosimetric Study of BANG Gel Calibration By T_2 Relaxometry

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Introduction

Radiation-sensitive polymer gel systems, such as BANG (1), are in increasingly widespread use for verification of proposed radiotherapy treatment plans, particularly in complex dosimetric situations (2). Most commonly, a large volume of gel is irradiated and its T_2 relaxation is mapped. Determination of radiation dose from this T_2 map requires prior calibration, which is usually achieved by obtaining a reference curve from smaller gel volumes irradiated to a series of known doses. This abstract explores the validity of such a calibration procedure and the validation of T_2 measurements made on a commercial MR scanner .

Methods

Experimental set-up: Experiments were performed using a Philips Gyroscan Intera 1.5T MR scanner (Philips Medical Systems, Best, The Netherlands) with a bird-cage head coil. Transverse relaxation times were measured using a 32-echo CPMG sequence. Pixel-by-pixel, single exponential fitting in Matlab (The MathWorks Ltd, Cambridge, UK) was used to generate T_2 maps, an example of which is displayed in figure 1.

Validation experiments: The accuracy and precision of T_2 measurements over the range 50-270 ms was assessed against values obtained on a 0.5T spectrometer. The effect of TR on the measured T_2 values was studied by varying TR between 100 and 10000ms for samples with T_2 in the range 57 to 865 ms. The effect of TR on SNR was also studied and compared with theoretical predictions, with NSA also varied to maintain a constant scan time. The homogeneity of T_2 measurements across the field of view was assessed over two perpendicular planes using a gel-filled 16cm diameter spherical test object.

Gel dosimetric accuracy with small vial calibration: 15 small volume vials (r=2.5cm) and 3 large volume vials (r=16cm) filled with BANG gel by the manufacturer (MGS Research Inc, Guilford, CT) were irradiated to differing dose levels (figure 1). Their T_2 values were mapped using a CPMG sequence with the following parameters: TE=15ms, Pixel size=5x1x1mm; NSA=2; Echoes = 32; TR=1500ms. Calibration curves for T_2 versus dose were produced separately for the large and small vials.

Results

Validation experiments: The T_2 values determined on the MR scanner correlated well with the spectrometer readings, giving a linear relationship between the two: the 1.5T MR scanner gave T_2 values consistently 4% higher than those obtained using the 0.5T spectrometer across a range of T_2 values from 50 to 270ms. The system was found to have excellent short term precision, with a mean co-efficient of variation (CV) of 0.2% (95% CI: 0.1 to 0.4%) in the T_2 range 50 to 270ms. The homogeneity of T_2 measurements across the field of view was found to be better than 1% for the range of T_2 values encountered used in gel dosimetry. Theoretical and experimental results for SNR optimisation were in accordance, giving optimal performance with TR 1500ms and NSA 2. On the basis of these results, these parameter values were used for subsequent experiments. Furthermore, results demonstrated that varying the TR has no significant affect on the measured T_2 with less than 1% variation in the studied ranges.

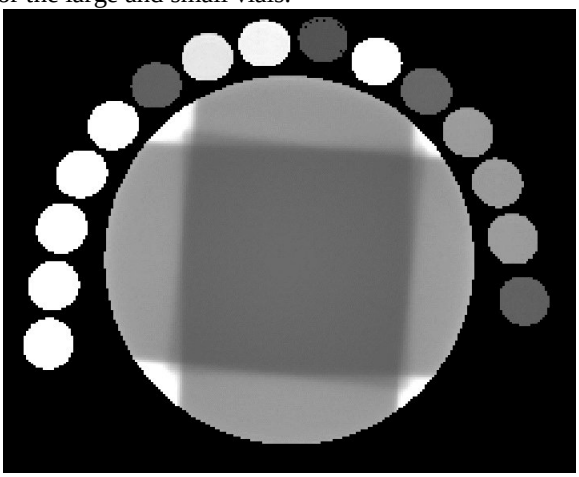

Figure 1. T_2 map of one large vial with adjacent calibration vials

Gel dosimetric accuracy with small vial calibration: The calibration curves generated from the two sizes of vial were statistically and clinically significantly different, such that if the small vial calibration curve was used to convert the large vials' readings to dose, the errors in resultant dose measurement may be as high as 15% (figure 2). In the range that would be clinically relevant for this experiment, the deviation of measured to delivered dose was between 6% and 14%.

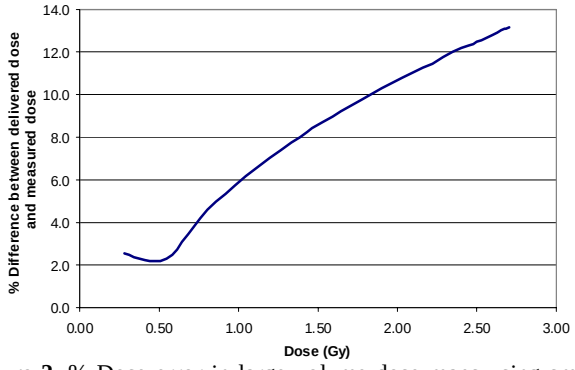

Figure 2. % Dose error in large volume dose maps using small vial calibration curve.

Conclusion

We have demonstrated an experimental protocol giving accurate and repeatable T_2 measurements for the purposes of radiation dosimetry using BANG gels. However, our results show that calibration of dose measurements in large phantoms using small volumes of gel may not be valid. In our experiments, such a procedure introduced errors of between 6% and 14% in the dose range of clinical interest. The source of these errors is not clear, but may relate to differences in the way in which gel sets in different sized vials.

References

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