Relaxometry changes in a gel dosimetry phantom due to continued RF exposure

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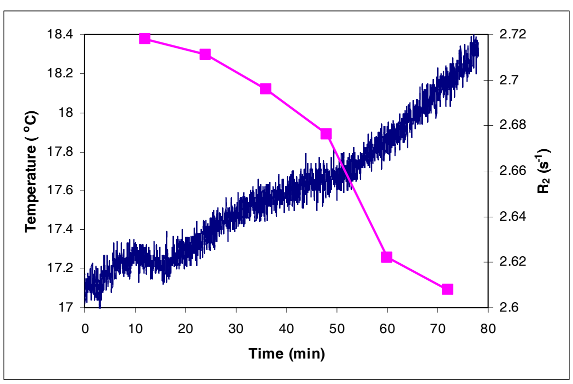
Introduction: As MRI-gel dosimetry becomes increasingly used in the field of radiotherapy verification, the accuracy of the technique needs to be thoroughly established. Among the MRI-dependent factors that have the potential to introduce errors into the final dose map, the heating of the gel from the measurement acquisition itself has been the least addressed. The necessary transverse relaxation time measurements require the use of multiple RF pulses and often repeat scanning in one flask is used to provide in situ calibration and/or for highly detailed plan verification. As the diameter of the phantom becomes comparable with (half) the resonant wavelength of the system, temperature increases are likely to be important. This study attempts to establish the tolerance for continued exposure to RF and map any spatial effects.

Materials & Methods: Imaging was performed on a 3.0 Tesla GE Signa scanner. A two-litre flask (12 cm diameter) containing a MAGIC-type gel medium widely used for gel-dosimetry was imaged, having been left overnight to reach ambient temperature. Two dual-echo FSE sequences (TE/TR = 30,105 & 60,180/4000 ms) as used in previous in-vivo and dosimetry studies, were acquired through the gel container with 5/1 mm slices and an in-plane resolution of 0.9 mm. Temperature was measured using an MR-compatible fluoroscopic probe and extension (Lambda photometrics). A needle and sheath was used to introduce the probe into the gel for ease and accuracy of positioning and then withdrawn leaving the probe in place. Measurements were taken at the edges and centre of the phantom during the acquisitions. Scanner bore temperature was also recorded before and after scanning. A total of seven repeat acquisitions were taken over a period of 72 minutes. R_2 was estimated at the end of each sequence in small regions-of-interest using a semi-weighted fit to the data. Pixel-by-pixel maps of ΔR_2 were also produced from each subsequent repeat measurement using in-house developed software (MATLAB).

Results: Bore temperature remained constant throughout. Temperature changes of up to 1.4 °C were observed at the edges of the flask and a concomitant decrease of R_2 by 4.0 %. Figure 1 plots the temperature distribution during the scanning together with R_2 measurements at the edge of the flask. In contrast, the centre of the flask demonstrated smaller changes with temperature and R_2 differences of 0.3 °C and 2.6 % respectively. Figure 2 shows maps of ΔR_2 calculated by subtracting each subsequent acquisition from the first R_2 map. This demonstrates the greater increase in temperature at the periphery of the flask and a much smaller and more gradual increase at the centre. The increase at the edges also appears asymmetrical.



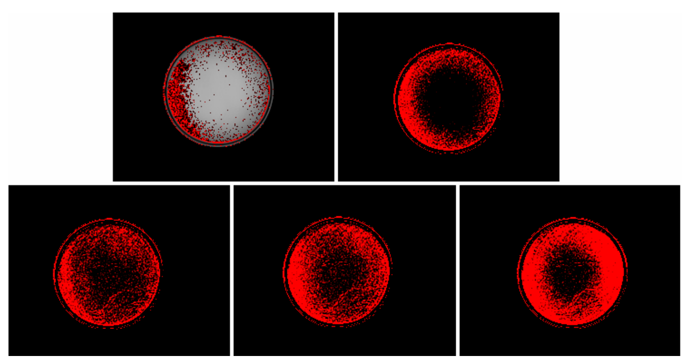


Figure 1: (Left) Plot of temperature (blue) and R_2 (pink) at the edge of the gel flask during scanning. Figure 2: (right) Pixel-by-pixel maps of ΔR_2 over time (top to bottom, left to right) show the evolution of the relaxation rate decrease due to temperature changes (T_2-weighted image of gel phantom also shown in first map).

Discussion: This study establishes that temperature is unlikely to cause a significant component of the final dose error if scanning is restricted to < 36 min. However, beyond this time, the heating effect at the edge of the dosimeter alters the relaxation time of the gel and this could translate to dose errors of greater than 3 %, which is the current limit of film dosimetry. It is of note that this temperature distribution is not uniform, and the maps of ΔR_2 are an effective way of mapping these RF heating changes and may be useful for investigating other sequences and systems.