The influence of temperature on polymer gel radiation dosimetry with MRI

Hiromi Sano[1,2], Takayuki Obata[3], Hiroshi Kawaguchi[1], Kuniaki Nabatame[2], Satoshi Obara[2], Jeff Kershaw[1], Keiichi Akahane[2], Yoshiya Shimada[2], and Hiroshi Ito[1]

[1]Molecular Imaging Center, National Institute of Radiological Sciences, Chiba, Chiba, Japan, [2]Medical Exposure Research Project, National Institute of Radiological Sciences, Chiba, Chiba, Japan, [3]Research Centre for Charged Particle Therapy, National Institute of Radiological Sciences, Chiba, Chiba, Japan

INTRODUCTION

Recent radiotherapy irradiates the subject from multiple directions (three-dimensional irradiation) to concentrate the dose in a specific target area. Unfortunately, there is a corresponding increase in the number of low dose regions for which theoretical dose estimation is difficult. Polymer gel dosimetry, which can measure the radiation dose via changes to the transverse relaxation rate R2, provides a means to three-dimensionally visualize the actual dose distribution with MRI [1]. A multi-slice (MS) Carr-Purcell-Meiboom-Gill (CPMG) sequence is often used to acquire high spatial resolution three-dimensional R2 images in a reasonable acquisition time. However, the high number of RF pulses needed for the MS method may increase the temperature of the polymer gel, which can cause errors in dose estimation because the R2 of a polymer gel depends on temperature as well as the radiation dose [2]. In this study, the relationship between changes to R2 and temperature caused by RF pulses was investigated in a polymer gel phantom.

MATERIALS AND METHODS

Experiments were performed using a Siemens Verio 3.0T MRI with a twelve-channel head matrix coil. A plastic bottle (ϕ 80 mm, height 146 mm) was filled with BANG3 polymer gel (MGS Research Inc.) to mimic tissue. The temperature of the gel phantom was recorded with a fluorescence thermometer (AMOTH FL-2000, Anritsu Meter Co. Ltd.). The optical fiber probe of the thermometer was inserted into the center of the polymer gel phantom through a hole made at the bottom of the plastic bottle and the temperature was measured during a MRI scan. The CPMG scan (acquisition time: 25 minutes) was repeated 17 times (7 hours) for acquisitions with a single slice (SS), 5 slices (MS5) and 11 slices (MS11). Other parameters were: TR = 6 s, minimum TE = 15.6 ms, number of echo = 32, echo step = 15.6 ms, field-of-view = 256 mm x 256 mm, in-plane pixel size = 1 mm x 1 mm, and slice thickness= 5 mm.

RESULTS AND DISCUSSION

The rate that the temperature of the polymer gel rose with MRI scan time depended on the number of slices (SS: 0.2 [^{o}C], MS5: 0.7 [^{o}C], MS11: 1.1 [^{o}C] after scanning for 7 hours). The R2 of the polymer gel clearly decreased in accordance with the number of slices and MRI scan time (Figure 1). A temperature rise of 1 [^{o}C] caused a 0.099 [s^{-1}] reduction in R2 (Figure 2). Previous work found a quadratic relationship between R2 and radiation dose for BANG3 polymer gel [3]. According to that relationship and assuming a temperature rise of 1 [^{o}C] (or ΔR2 of -0.099 [s^{-1}]), errors in the estimated radiation dose would be -2.28% (from 2.87 to 2.80 Gy), -3.94% (from 2.12 to 2.04 Gy) and -8.49% (from 1.19 to 1.09 Gy) if the true R2 (i.e. no contamination by temperature changes) were 6, 5, and 4 [s^{-1}], respectively, which indicates that dosimetry in lower dose regions is sensitive to temperature.

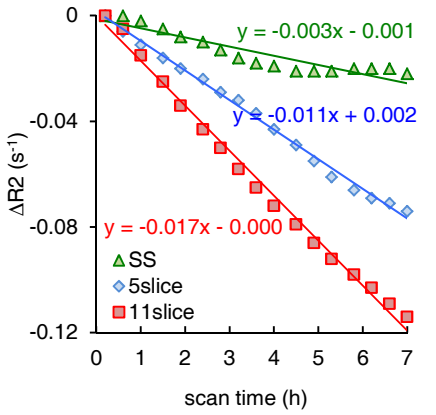

Fig. 1 Changes to ΔR2 as a function scan time and the number of slices

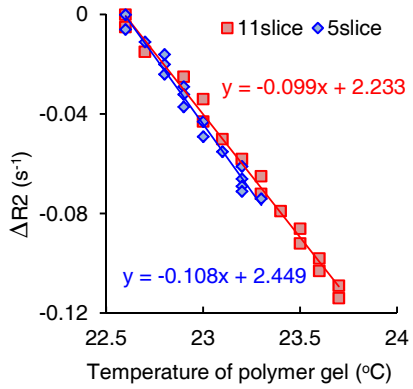

Fig.2 Relationship between ΔR2 and gel temperature

CONCLUSIONS

The R2 of a polymer gel phantom decreased due to a temperature rise caused by RF pulses. Since MS imaging is required to measure the spatial distribution of radiation dose in a practically achievable scan time, temperature control and/or correction is needed to reduce errors in dose estimation. Although several polymer gels have been suggested for dosimetry with MRI, the impact of temperature changes due to RF pulsing has received little attention. The results of the present study suggest that understanding changes to polymer gel temperature is important to perform accurate polymer gel dosimetry with MRI. In future work, we will perform similar experiments for BANG3 polymer gel after irradiation because a previous report showed that the dependence on temperature is enhanced after irradiation for another type of polymer gel [2].

REFERENCES

[1] Y De Deene.J. Phys.: Conf. Ser. 250:012015(2010)
[2] J Vandecasteele and Y De Deene.Phys.Med.Biol, 58:43-61(2013)
[3] Y Watanabe and Y Nakaguchi, Med.Phys, 40:082101(2013)