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Verification of the Post Time Dependence of MAGICA Polymer Gel Dosimeter with Electron Beams Using MRI Technique

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ABSTRACT

In this work investigation of the normoxic MAGICA polymer gel dosimeter such as R2-dose response with post time MAGICA polymer gel dosimeter have been undertaken. Using MRI, the formulation to give the maximum change in the transverse relaxation rate R2 was determined to be 8% gelatin, 0.5% agarose, 9% methacrylic acid, 0.0352% ascorbic acid, 0.0015% CuSO4.5H2O, 0.002% hydroquinone and 82.3% HPLC(Water).Irradiation of vials was performed using Electron beams by Elekta linear accelerator. Gel dosimeters were imaged in a Siemens Symphony 1.5 Tesla clinical MRI scanner using a head coil. Gel dosimeters were irradiated 1 day post-manufacture, and imaged 1 day post irradiation. The response of the MAGICA gel is very similar in the lower dose region and the R2-dose response for doses less than 250 cGy is not exact. The R2-dose response of the MAGICA polymer gel dosimeters varies between 500cGY to 1750 cGy with R2-dose sensitivities of 0.002 and 0.0023 S-1 cGy-1 when imaged at 1 and 8 days post-irradiation respectively.
Key word: Post Time Dependence, Electron Beam, MAGICA, MRI.

INTRODUCTION

Gel dosimetry systems are the only true 3-D dosimeters. The dosimeter is at the same time a phantom which can measure absorbed dose distribution in a full 3-D geometry. Gel dosimeters are integrating dosimeters with the capability of capturing the whole dose distributions inside them and with versatility to be shaped in any humanoid form which makes them unique in their kind and potentially very suitable for the verification of complex dose distributions as they occur in clinical settings such as radiotherapy. Currently, two types of gel dosimeters can be distinguished: Fricke gels, based on well established Fricke dosimetry, and polymer gels. Both systems consist a ydrogel matrix that preserves the spatial distribution of absorbed dose in the dosimeter. In Fricke gel dosimeters it is the concentration of ferric ions, and in polymer gel dosimeters the concentration of polymer aggregates that is correlated with the absorbed dose. Although, many researchers have contributed to the further development of Fricke gel dosimetry but nowadays, there is a trend towards polymer gels rather than Fricke gels which is due to the diffusion effects in the latter which restricts its usefulness and applicability. Polymer gels are an emerging new class of dosimeters which are being applied to the challenges of modern radiotherapy modalities. In this study, investigation of the MAGICA polymer gel dosimeter (R2- dose response and post time) has been undertaken. In this study, MRI technique was used to determine the response of the normoxic MAGICA polymer gel dosimeter.

METHODS AND MATERIALS

MAGICA Preparation:

MAGICA polymer gel dosimeter was prepared. All chemicals (gelatin, ascorbic acid,

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cuso4.5H2O, hedroquanine and methacrylic acid) were provided by Sigma Aldridge and Flucka with experimental grade. HPLC water was obtained from Novin Medical Radiation Institute in Tehran. The preparation of the gel was carried out a similar procedure as described by Fong et al. (2001) with slight difference due to the presence of Agarose in MAGICA formulation. First, water was divided into 5 flasks of varying sizes beforehand, ready for dissolving each substance. Gelatin was added in to about 60% of the total HPLC de-ionized water. Two electrical heating plates provided with magnetic stirring and thermostatic control were used to heat the solutions. Gelatin was allowed to swell for about an hour and then the solution was stirred and heated to about $50^{\circ}C$ until a clear solution was obtained, ensuring all gelatin has been dissolved. When the gelatin solution temperature reached near 40 $^{\circ}C$, Agarose is added to about 30% of warm water which has been heated up to 50 $^{\circ}C$ beforehand. Agarose solution was stirred and heated to about 90 $^{\circ}C$ at which Agarose was thoroughly dissolved. At this time gelatin solution should have reached near 50 $^{\circ}C$. Both solutions were allowed to cool. The gelatin solution was larger in volume compared to the Agarose solution, thus Agarose solution cools faster in spite of its higher temperature. However, the cooling rates can be adjusted with respect to each other by proper adjustment of the heating plates. When both solutions cooled to an equal temperature about 47 $^{\circ}C$, Agarose solution was added to the gelatin solution and stirring continued. Stirring never stops before the end of fabrication. At 45 $^{\circ}C$, Hydroquinone which has been solved in about 5% of water was added to the mixture. The remaining 5% of water were divided into two portions and in each portion Ascorbic acid (AA) and Copper (II) sulphate were dissolved after being weighed. These two chemicals which together play the role of oxygen scavenger were added to the mixture when temperature decclined to about 37 $^{\circ}C$. Methacrylic acid(MAA) was added at the same temperature and the stirring was continued. The amount of MAA for all gel fabrications was 9% of the total weight of gel except in one experiment in which more MAA was used. The gel was then decanted into test tubes or poured into the phantoms and left in a typical refrigerator at about 4 $^{\circ}C$ to set. Gel phantoms and calibration tubes were not irradiated in the first 24 hours after being manufactured. All irradiations were performed this period. Table1 lists the components with different percent weight in normoxic MAGICA polymer gel dosimeter.

Table 1. Different chemicals and percent weight of MAGICA gel.

Component	Percent Weight
Gelatine	**8%**
Agarose	**0.5%**
Methacrylic Acid	**9%**
Ascorbic Acid	**0.0352%**
CuSO4.5H2O	**0.0015%**
Hydroquinone	**0.002%**
HPLC(Water)	**82.3%.**

Irradiations:

Irradiation of vials was performed using electron beams by Elekta linear accelerator with SSD =100cm, field size of $20 \times 20 cm^2$ and the depth was selected at 1cm. The optimal post-manufacture irradiation was determined to be 1 day.

Imaging:

The MAGICA polymer gel dosimeters were imaged in a Siemens Symphony 1.5 Tesla clinical MRI scanner using a head coil. T2 weighted imaging was performed using a standard Siemens 32-echo pulse sequence with TE of 20 ms, TR of 3000 ms, slice thickness of 4 mm, FOV of 256 mm. The optimal post imaging times was determined to be 1 day. The images were transferred to a

personnel computer where T2 and R2 maps were computed using modified radiotherapy gel dosimetry image processing software coded in MATLAB (The Math Works, Inc).The mean T2 value of each vial was plotted as a function of dose with the quasi-linear section being evaluated for R2-dose sensitivity.

RESULTS

R2-dose sensitivity of MAGICA polymer gel dosimeter:

MAGICA gels with optimum value of ingredient was manufactured and irradiated to different doses. As it can be seen in figure 1, MAGICA had a linear response up to 4000 cGy. The responses of the MAGICA gel were close to each other in the

lower dose region (0-250 cGy) which meant the dosimeter was not accurate in doses less than 250cGy.The response was linear between 500 – 1750cGy and 1750-4000 cGy respectively with different slope (0.002 and 0.0072 s-1cGy-1)(Table 2).Polymer gel dosimeters in Perspex phantoms were homogeneously irradiated with 6MeV electron beam with an Elekta Linear accelerator located in Tehran. Delivered doses were from 0-4000MU. The calibration curve (transverse relaxation rate (1/2) versus applied absorbed dose) was obtained and plotted.

Table 2. Sensitivity of MAGICA with different range of doses

Dose(cGY)	R2-dose sensitivity(s-1cGy-1)	Correlation Coefficient
0-250	0.00003	1
500-1750	0.002	0.892
1750-4000	0.0072	0.9843

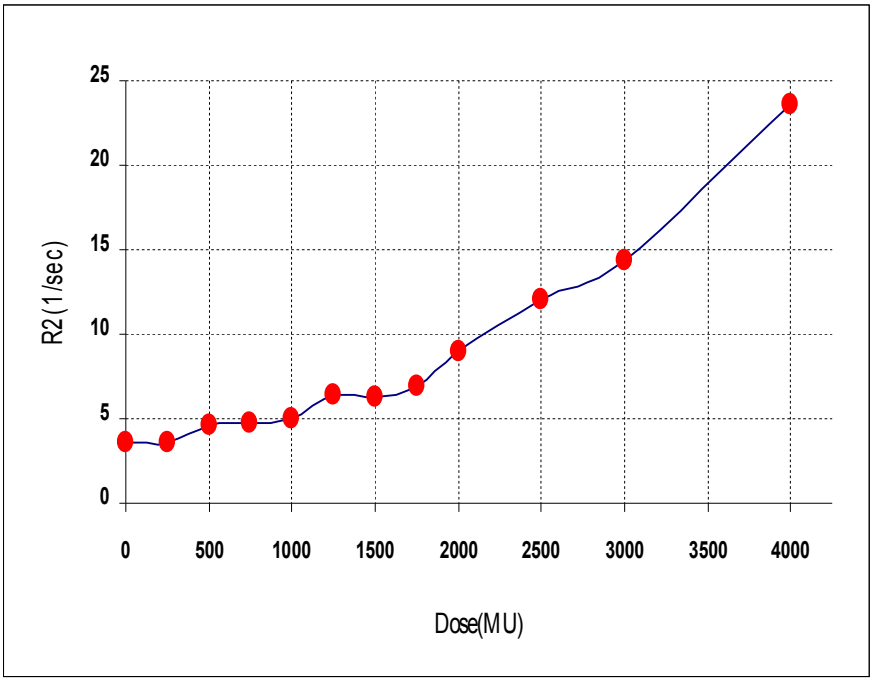

Fig. 1. MAGICA polymer gel dosimeter 1/T2 response on absorbed dose in range of 0-4000MU

Variation of R2-dose Response of MAGICA gel dosimeter with Post irradiation Time:

The R2-dose response of the MAGICA polymer gel dosimeter was linear between 500-1750 cGy and 1750-4000cGy doses. Figure 2 shows the R2-dose response with time (e.g. 1 and 8 days). In this study the R2-dose response was linear up to 1750 cGy with R2-dose sensitivities of 0.002 and 0.0023 S-1cGy-1 when imaged at 1and 8 days post-irradiation respectively.The R2-dose sensitivity showed stability with post time imaging after 8 days. Table 3 lists the R2-dose sensitivity and correlation coefficients for the two post-irradiation imaging times. This study has shown that the normoxic MAGICA polymer gel dosimeter has the properties of a dosimetric tool, which can be used in clinical radiotherapy for a period of up to 8 days without changing the sensitivity (figure 3).

Table3. R2-dose sensitivity and correlation coefficients for the two post-irradiation imaging times

Image Time Post Irradiation(day)	R2-dose sensitivity(S-1cGy-1)	Correlation Coefficient
1	0.002	0.892
8	0.0023	0.8924

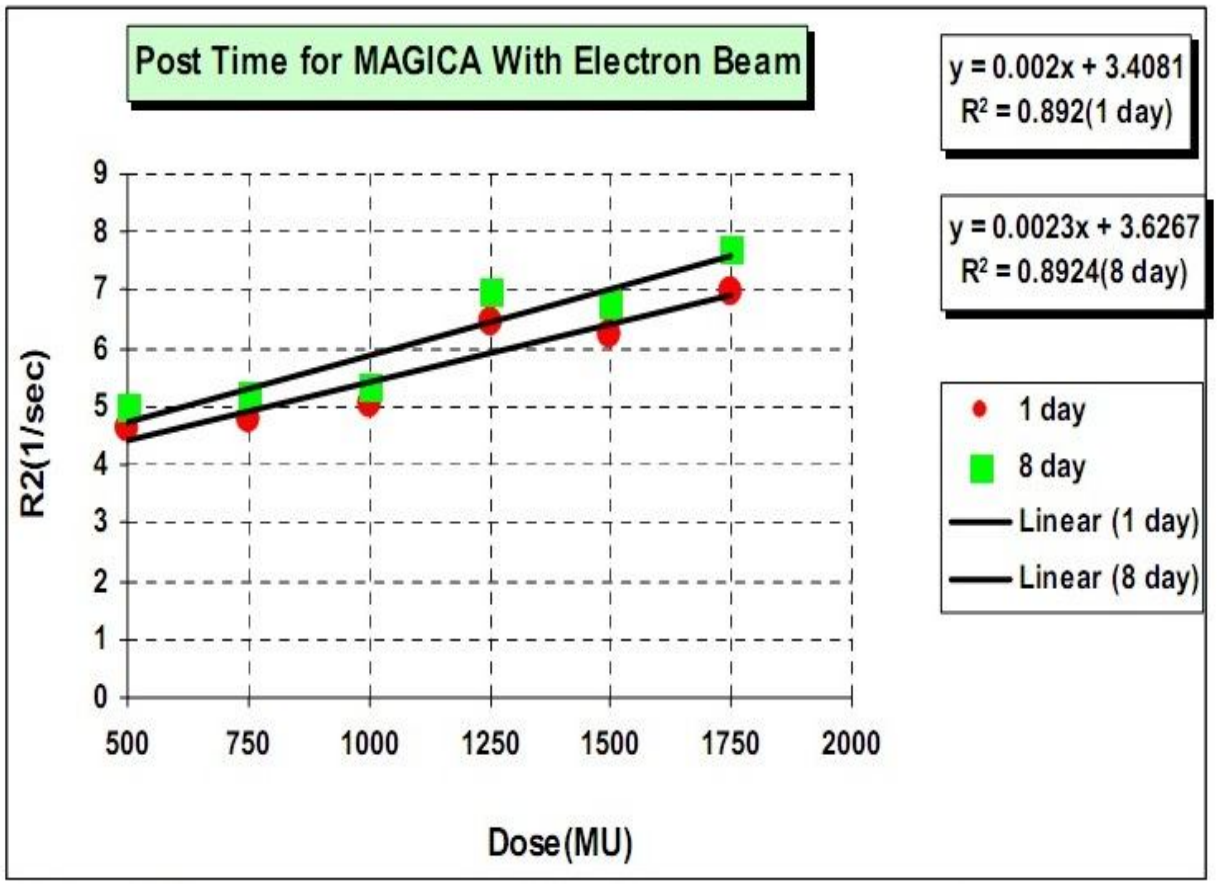

Figure 2. R2-dose response curve of the MAGICA polymer gel dosimeter evaluated at 1a 8 days post-irradiation.

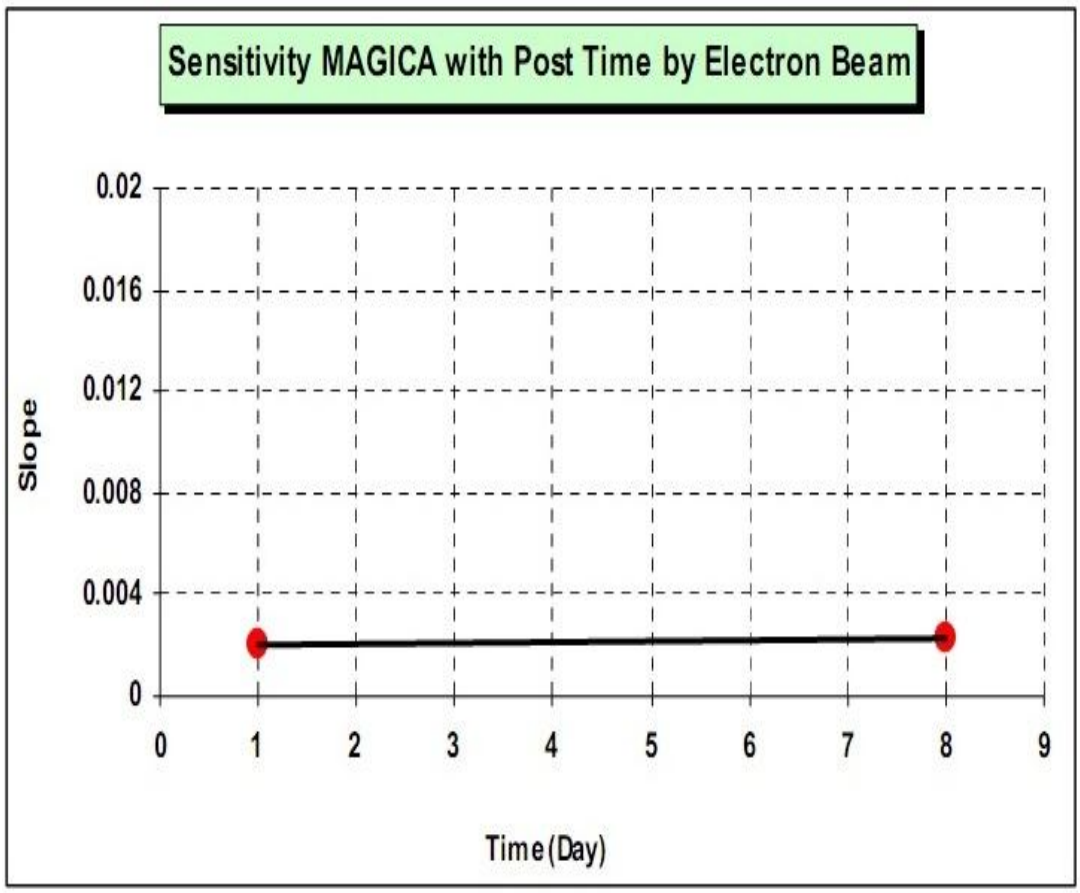

Figure 3. the R2-dose sensitivities of 0.002 and 0.0023 S-1cGy-1 at 1a 8 days post-irradiation.

Conclusions

In 2004 Scheib and colleagues research on the BANG gel, they concluded that 1.25MeV proton can storage time the gel for 10 days. Zahmatkesh et al in 2004 research on the MAGICA gel, they concluded that 60Co can storage time the gel for 10 days.In 2005 Vening et al colleagues research on the PAGAT gel, they concluded that 60Co can storage time the gel for up 24 days.In study MAGICA gel can storage time for up 8 days.

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