



RESEARCH PAPER

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Comparison of dose rate dependence in MAGICA and PAGAT gel dosimeters (*Soft Tissue Equivalent*) with electron beams using MRI

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Abstract

The purpose of this study was to evaluate the dependence of MAGICA and PAGAT polymer gel dosimeters $1/T_2$ on different electron energies in order to compare the dose rate dependence of MAGICA and PAGAT polymer gel dosimeters in electron beams using MRI technique for a standard clinically used an ELEKTA linear accelerator. Using MRI, the formulation to give the maximum change in the transverse relaxation rate R_2 ($1/T_2$) was determined MAGICA gel dosimeter and PAGAT gel dosimeter. In this work the response of MAGICA gel is very similar in the lower dose region and the R_2 -dose response for doses less than 250cGy is not exact. Dose rate of dependence was studied in 10MeV electron beam with the use of dose rates 80,160,240,320,400 and 480MU/min. The response of PAGAT gel is very similar in the lower dose region and the R_2 -dose response of the PAGAT polymer gel dosimeter is linear between 10 to 30Gy and dose rate dependence was studied in 6MeV electron beam with the use of dose rates 80, 160, 240, 320, 400 and 480cGy/min. In this study no trend in polymer-gel dosimeter for MAGICA and PAGAT $1/T_2$ dependence was found on mean dose rate for electron beams.

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Introduction

Gel polymer gel in which the components of the polymer network. Network polymer network forming a covalent or physical aggregation requirements. Gel dosimetry systems. the radiation dose is measured in 3D geometry. Dosimeter phantom that can be simultaneously absorbed dose distribution in a full three-dimensional geometry to measure Complex three-dimensional geometry of dosimeters can be made into humanoid form and measure the dose of radiation to be unique and can be used in clinical settings (Vergote, 2005; Venning et al., 2004).

In 1984, magnetic resonance imaging (MRI) visualization of three-dimensional (3D) dose distribution using ferric sulfate or ferrous gel dosimeters have been used. After that, a study to determine the feasibility of using iron gel as a 3D dosimetry system in radiation oncology was performed. The major limitation is that the effect of iron gel dosage suffers blur over time due to the migration of ferrous and ferric ions in the gel matrix, this occurs (Gore et al., 1985; Olsson et al., 1990; Schulz, 1990).

In 1993, a polymer gel dosimeters was developed by the location of the beam using MRI showed. Polymer gel dosimetry is a technique capable of mapping dose distributions in three dimensions with high spatial resolution shows. Measurement of radiation dose distributions using a polymer gel has a number of advantages over other traditional dosimeters such as ionization chambers, thermo luminescent dosimeters (TLD) and a radiographic film. These include the independence of the radiation equivalence of soft tissue integration dose for the treatment of a number of fields in a row , and perhaps more importantly , to assess the full amount at once (Maryanski et al., 1993; Deene, 2004).

In 2001, the first normoxic gel was proposed, which can calculate the dose of radiation in natural conditions. Magnetic Resonance Imaging (MRI) has been widely distributed for assessment of absorbed dose in polymer gel dosimeters used. MRI evaluation

of polymer gel dosimeters, radiation dosimeters changes in T2 as a result of changes in the physical density of the polymer gel. Many factors , including polymer gel composition , temperature changes during irradiation , the type and energy of radiation, dose rate , temperature in check MRI, the time between exposure to reviewing MRI, and magnetic field strength has been studied by several authors (Brindha et al., 2004; Fong et al., 2001).

All these factors can potentially affect the response of polymer gel dosimeters. Consequently, in order to investigate and quantify each of the individual factors are important. In this study, we evaluated the dependence of the dose rate MAGICA and PAGAT gel dosimeters with electron beams using MRI done. In this regard, MRI to determine the response of polymer gel dosimeters were used MAGICA and PAGAT.

Materials and methods

Preparation of MAGICA and PAGAT gel dosimeters

Preparation of MAGICA gel

MAGICA polymer gel dosimeters have been developed. All chemical ingredients include gelatin, ascorbic acid, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, hydroquinone acid, methacrylic. These materials are made by Sigma-Aldrich and FLUCKA high purity. Water HPLC gel dosimetry is made in the laboratory. First, the water bottle in 5 different sizes to solve the material pre- divided. About 60 % of gelatin was added to HPLC. Two electric heating and a magnetic stirrer and a thermostatic control solution was used for heating. Gelatin, soaked in water for about an hour, and then the solution was stirred and heated to 50 ° C to obtain a clear solution , then ensure complete solution of gelatin and gelatin when the temperature rose to 40 ° C , agarose to 30 % of the water temperature reached 50 ° C is added to it already . Agarose solution was heated to 90 ° C and stirred. When the gelatin solution temperature to 50 ° C is reached . Both solutions are then cooled. More than agarose gelatin solution and its temperature is lower, but despite the higher temperature agarose cools faster than gelatin . However, the cooling rate can be fit using a heating

pad set. When both soluble same temperature reached about 47 ° C, agarose solution was added to the gelatin solution to be stirred . Stirring until the construction never stops. Hydroquinone solution at 45 ° C in 5 % water is added to the mix. The remaining 5 percent is divided to two parts water and ascorbic acid and copper sulfate is dissolved in them. These two chemicals are the Scavenger oxygen at 37 ° C was added to the solution. Meta acrylic acid solution was added and stirring at the same temperature would continue. MAA 9 % of the total weight of the gel is. The gel is then poured into test tubes and the phantom in the ordinary fridge temperature is about 4 degrees Celsius. Gel phantoms and calibration tubes were not irradiated in the first 24 hours after being manufactured. All irradiations were performed this period (Fong et al., 2001).

Preparation of PAGAT gel

PAGAT polymer gel formulation by % mass consisted of 4.5% N,N'-methylene-bisacrylamide (bis), 4.5% acrylamid (AA), 5% gelatine, 5 mM tetrakis (hydroxymethyl) phosphonium chloride (THPC), 0.01 mM hydroquinone (HQ) and 86% HPLC(Water) . All components were mixed on the bench top under a fume hood. The gelatine was added to the ultrapure de-ionized water and left to soak for 12 min, followed by heating to 48°C using an electrical heating plate controlled by a thermostat. Once the gelatine completely dissolved the heat was turned off and the cross-linking agent, bis was added and stirred untiled dissolved. Once the bis was completely dissolved the AA was added and stirred untiled dissolved. Using pipettes, various concentration of the polymerization inhibitor HQ and the THPC anti-oxidant were combined with the polymer gel solution. When the preparation of final polymer gel solution is completed, it is transferred into phantoms and allowed to set by storage in a refrigerator at about 4°C (Venning et al., 2005).

Irradiation

Irradiation of vials was performed using an ELEKTA linear accelerator with SSD =100cm, field size= 20* 20 cm² , dose rate=400 cGy/ min and the depth was

selected 1cm for MAGICA and 5cm for PAGAT . The optimal post-manufacture irradiation was determined to be 1 day.

Imaging

The MAGICA and PAGAT 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 and discussion

Comparison of calibration methods normoxic polymer gel dosimetry of MAGICA and PAGAT polymer gel dosimeters with electron beams:

Calibration of MAGICA gel dosimeter with electron beams

MAGICA gels with optimum value of ingredient was manufactured and irradiated to different doses. As it can be seen (Fig 1), MAGICA has a linear response up to 4000cGy. The responses of the MAGICA gel were close to each other in the lower dose region (0-250cGy) which meant the dosimeter was not accurate in doses less than 250cGy.The response was linear between 500 – 1750cGy and 1750-4000cGy respectively with different slope (0.002 and 0.0072 s-1cGy-1).(Table1). Polymer gel dosimeters in Perspex phantoms were homogeneously irradiated with 10MeV electron beam with an ELECTA Linear accelerator located in Tehran. Delivered doses were from 0-4000cGy. The calibration curve (transverse relaxation rate (1/2) versus applied absorbed dose) was obtained and plotted.

Calibration of PAGAT gel dosimeter with electron

beams

PAGAT gels with optimum value of ingredient was manufactured and irradiated to different doses. Polymer gel Dosimeters in Perspex phantoms were homogeneously irradiated with 6MeV electron beam with an ELECTA linear accelerator located in Tehran. Delivered doses were from 0-6000cGy. The calibration curve (transverse relaxation rate ($1/T_2$) versus applied absorbed dose) was obtained and

plotted. Dependence of $1/T_2$ response to the absorbed dose in the range of 0-6000cGy is shown in figure 2. As it can be seen in figure2, PAGAT has a linear response up to 30Gy. The response of the PAGAT gel is very similar in the lower dose region and the R2-dose response for doses less than 3Gy is not exact. The R2-dose response of the PAGAT polymer gel dosimeter is linear between 3-10Gy and 10-30Gy.

Table 1. 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

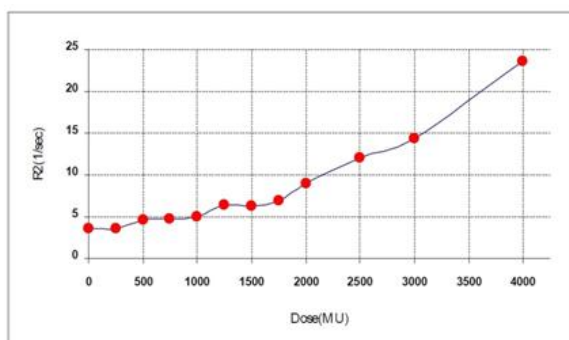


Fig. 1. MAGICA polymer gel dosimeter $1/T_2$ response on absorbed dose at range of 0-4000MU.

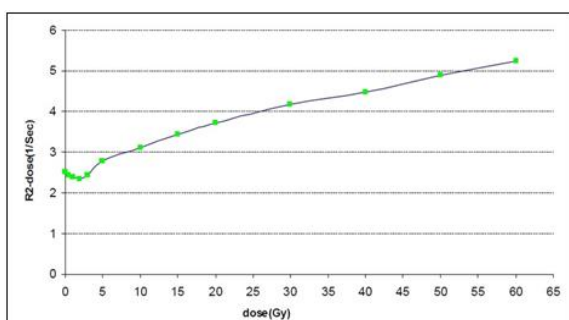


Fig. 2. Sensitivity of PAGAT gel with different range of doses (0-60Gy) in electron beam.

Verification of R2-dose response of MAGICA and PAGAT gel dosimeter with dose rate in electron beams:

Verification of R2-dose response of MAGICA gel dosimeter with dose rate in electron beams

Dose rate dependence for MAGICA gel was verified in figure 3. With a 10 MeV electron beam 1000 cGy dose was delivered to the gel phantoms with dose rates

varying from 80,160,240,320,400 and 480 cGy min⁻¹. A line was fitted to the data which shows no significant dependence of R2 to dose rate.

Verification of R2-dose response of PAGAT gel dosimeter with dose rate in electron beams

Dose rate dependence for PAGAT gel was verified in figure (4) with a 6MeV electron beam 20Gy dose was delivered to the gel phantoms with dose rates varying from 80, 160, 240, 320, 400 and 480 cGy/min. A line was fitted to the data which shows no significant dependence of R2 to dose rate.

Discussion and conclusion

According to the best knowledge of the authors only a few studies were published to evaluate dose rate dependence for the polymer gel dosimeters. Ibbott et al., which worked on BANG polymer gel, concluded that the polymer gel dose response is independent of both dose rate and beam modality and used the polymer gel calibration curve determined with 6 MV x rays for evaluation of the gel dosimeter irradiated with ⁶⁰Co without any limitations or approximations(Ibbott et al., 1997). Maryanski et al. used central axis percentage depth dose of 6 MV x-ray and 15 MeV electron beams measured in the BANG-2 gel dosimeter (composed of: 5% Gelatin, 3% N,N'-methylenebis-acrylamide(BIS), 3% Acrylic acid, 1% NaOH & 88% Water) and compared them with diode measurements in water. They concluded that there is

no energy as well as dose rate dependence of gel dosimeter for electron beams in the range 2-15MeV and dose rates in the range 20-400MU/min(Maryanski et al., 1996). They found that gel response is independent to the dose rate. This is similar to our work however the ingredients in BANG-2 and PAGAT are totally different. Therefore no significant dose rate effects in MAGICA and PAGAT polymer gel have been observed using NMR evaluation when dose rate is changed from 80cGy/min to 480cGy/min.

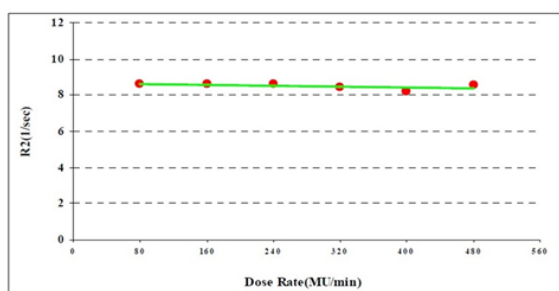


Fig. 3. Verification of MAGICA gel dosimeter response to electron beam dose rates.

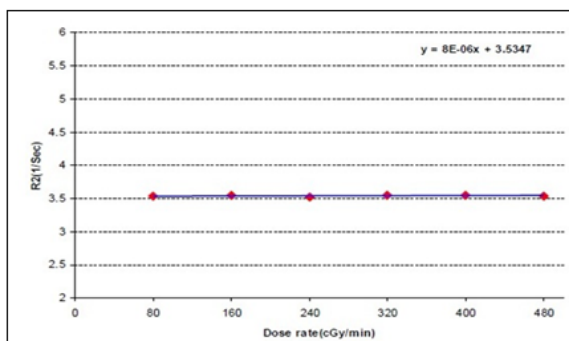


Fig. 4. Verification of PAGAT gel dosimeter response to electron beam dose rates.

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