Global Journal on Advances in Pure & Applied Sciences

Issue 7 (2016) 102-107

Selected Paper of 2nd World Conference on Health Sciences (H-SCI 2015)
30 April-02 May 2015 Efes Sürmeli Hotel & Convention Center – İzmir, Kuşadası, Turkey

Percentage depth dose (PDD) and Beam profile measurements using CT based MAGAT gel dosimetry system and Monte Carlo calculation

Mohammad Aljamal*, Department of Medical Radiation, Faculty of Allied Medical Sciences, Arab American University, Jenin, Palestine.

Ahmad Zakaria, Department of Medical Radiation, University Sains Malaysia, Health campus, Kelantan, Malaysia.

Suggested Citation:

Aljamal, M. & Zakaria, A. (2016). Percentage depth dose (PDD) and Beam profile measurements using CT based MAGAT gel dosimetry system and Monte Carlo calculation, *Global Journal on Advances in Pure & Applied Sciences.* [Online]. 07, pp 102-107. Available from: www.propaas.eu

Received November 20, 2014; revised December 07, 2014; accepted March 06, 2015.
Selection and peer review under responsibility of Prof. Dr. Fahrettin Sadikoglu, Near East University.

Abstract

The aim of this project is to develop and to evaluate the CT based MAGAT (methacrylic acid, gelatine and tetrakis phosphonium chloride) polymer gel dosimetry for measuring 3D dose distributions in radiation treatment. The MAGAT gel was prepared based on the formulation proposed in the literature. The percentage depth dose (PDD) and beam profile of 8 x 8 cm2 field size photon beam from a 6 MV linear accelerator were measured. Monte Carlo simulation was carried out to calculate PDD and beam profiles in the simulated MAGAT gel phantom to verify the data measured using MAGAT gel dosimetry for the 8 x 8 cm2 field size. The PDD and beam profile calculated using simulated MAGAT gel phantom agreed very well with that measured using MAGAT gel dosimetry. However, there were some differences between the simulated PDD with that measured at the surface region due to the electron contamination at the surface of the simulated phantom. In conclusion, the results showed that the CT based MAGAT gel dosimetry system is promising method to measure three-dimensional dose distribution based on PDD and Beam profile measurement.

Keywords: MAGAT gel, CT, Monte Carlo simulation

* ADDRESS FOR CORRESPONDENCE: **Mohammad Aljamal,** Department of Medical Radiation, Faculty of Allied Medical Sciences, Arab American University, Jenin, Palestine. *E-mail address*: mohammad.aljamal@aauj.edu

1. Introduction

Polymer gel dosimetry showed the ability to measure three dimensional dose distribution of radiation treatment [8]. The previous types of gel dosimeters have been limited in clinical use due to difficulty of preventing of oxygen from penetrating the gel mixture. Oxygen acts as inhibitor of free radicals production and must be removed from gel dosimeters before irradiation, otherwise the polymerization process will be inhibited [14, 15]. One of the methods that was proposed to reduce the effect of oxygen in gel mixture by binding the oxygen with metallo-organic compounds [9]. The first gel dosimetry prepared in normal atmospheric conditions was named MAGIC (Methacrylic and Ascorbic acid in Gelatin Initiated by Copper) gel [9]. Since the ability to prepare this type of gel under normal atmospheric conditions, the gel is called normoxic polymer gel. Later, De Deene et al. (2002) [7] investigated various oxygen scavengers and it was found that tetrakis (hydroxymethyl) phosphonium chloride (THP) was effective at scavenging oxygen [7]. De Deene et al. (2002) [7] proposed a new formulation consisting of methacrylic acid, gelatine and THP, named as MAGAT (methacrylic acid, gelatine and THP) gel. The different types of normoxic gel dosimeters have been reviewed by Baldock and colleagues [4].

The most method of choice to extract dose information from gel dosimeter has been magnetic resonance imaging [3, 10, 11]. However, this technique showed some limitations such as the changes in temperature of gel dosimeter during imaging process, which markedly affects the spin-spin relaxation time (T2) [6]. Also, the lengthy imaging times is included in the current limitations of MRI imaging [13]. The advantages of CT scanner compare to other methods to extract dose information are: availability of CT to clinical radiation therapy for treatment planning purposes, simplicity & rapidity of image acquisition, and relatively insensitive to environmental factors. The CT based MAGAT gel dosimetry provides high dose resolution with dose sensitivity of 0.8 [5]. So far no study has been conducted to extract PDD and Beam profile measurement using CT scanner on irradiated MAGAT gel, which is a very important step for dose verification in radiotherapy treatment.

2. Methods and Materials

2.1. Gel preparation and irradiation

The MAGAT (Methacrylic Acid, Gelatin and Tetrakis (hydroxymethyl) phosphonium chloride) gel dosimeter was prepared based on a method proposed in the literature by De Deene et al. [7]. The chemical materials used to produce the gel were 9% Methacrylic acid, 8% Gelatin type A (300 bloom), 0.19% Tetrakis (hydroxymethyl) phosphonium chloride (THP) and 83% deionised water. A 2.7 liter volume of MAGAT gel dosimeter was prepared. The appropriate amount of gelatin was poured into the deionised water in 5 liter glass flask. After the gelatin has dissolved completely, the solution was heated to 48° C with stirring. Then the mixture was allowed to cool down to 40° C before the appropriate amounts of methacrylic acid and THP were added to the flask. The gel was poured into a plastic container (14 cm x 14 cm x 14 cm) made out Polypropylene. The container was sealed with plastic lid and stored in a refrigerator at temperature 4° C for 24 hrs. Before the irradiation of the gel, the unirradiated gel was scanned using Computed Tomography (CT) scan and the images were used to create the gel phantom for Monte Carlo simulation purposes. The gel dosimeter was then irradiated using a 6 MV photon from linear accelerator (Siemens Primus, USA) to 10 Gy with 8 x 8 cm^2 field size, SSD = 100 cm at room temperature as shown in Figure 1.

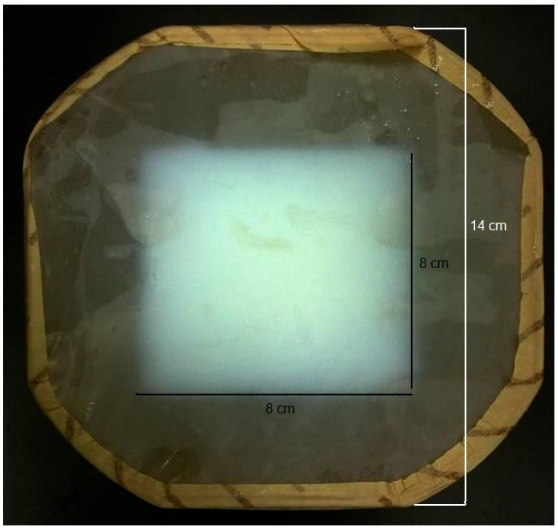

Figure 1. The gel after irradiation to single beam

2.2. CT imaging

The irradiated sample inside cylindrical Perspex phantom filled with water was scanned using diagnostic CT scanner (Siemens Medical Solution, Malvern, USA), 48 hours after irradiation to ensure the polymerization process was completed. Scanning parameters chosen were: 140 kV, 400 mAs, and 3 mm slice thickness. The gel dosimeter was scanned 20 times for image averaging process. OsiriX imaging software was used to save the axial and coronal slices of the sample in DICOM format to be analyzed in personal computer using ImageJ (developed at the US National institutes of health) software. The process of image averaging for the sample images was carried out. The coronal slices were used to determine PDD by drawing a straight line from the top to the bottom of the central axis of coronal slice. The function of the straight line is to plot the averaged CT number versus the depth. After the average CT number was determined for each depth in the central axis of the beam (center of the slice), the dose at that depth was obtained from calibration curve [1]. The percentage depth dose (PDD) curve at a particular depth was derived from the dose values obtained.

The isodose curves were obtained by drawing a straight line from the right to the left of the central axis in the slice to get the average CT numbers at different points along the straight line corresponding to 1.5 cm, 5 cm and 10 cm depths below the surface of the gel. Then the average CT numbers obtained at various points were used to produce isodose curve.

2.3. Monte Carlo simulation

The Monte Carlo simulation was carried out using BEAMnrc and DOSXYZnrc codes to perform all dose calculation [12]. The Monte Carlo simulations were run using a computer with Intel (R) Xenon processor of 2.2 GHz speed. Primus Linear accelerator head geometry (Siemens Primus, USA) was modeled using BEAMnrc program to carry out Monte Carlo simulation [2]. The BEAMnrc simulation was run to create a phase space file with 8 x 8 cm^2 field size to be used for MAGAT gel simulation and to be able to compare the results for this field size with that obtained in the experimental measurements. The parameters used were mentioned elsewhere [1]. The CT scan images of unirradiated gel were used to create the gel phantom for simulation purpose. The phase space files created by BEAMnrc were scored in the center of gel phantom. A total of 2 x 10^9 histories were run in the simulation. The PDD and isodose curve for the simulated gel phantom at dmax and 10 cm depths were calculated. The PDD and isodose curves for the simulated gel were matched with that measured using CT based MAGAT gel dosimetry for comparison purposes.

3. Results and discussion

The percentage depth dose (PDD) versus depth for the 6 MV photon with field size of 8 x 8 cm^2 obtained using simulated MAGAT gel dosimetry, experimental MAGAT gel measurement are shown in Figure 2. The value of simulated PDD obtained at the surface of the gel dosimetry was 40.6% while, that measured from gel dosimetry was found to be 53%. The maximum disagreement of PDD at 1.5 cm depth between simulated and measured gel dosimetry was found to be ± 0.2%. At 10 cm depth, the variation between simulated and measured PDD was found to be ±2%. Beyond dmax area, the maximum disagreement of simulated PDD compare to gel dosimetry measurements was found to be ±3%.

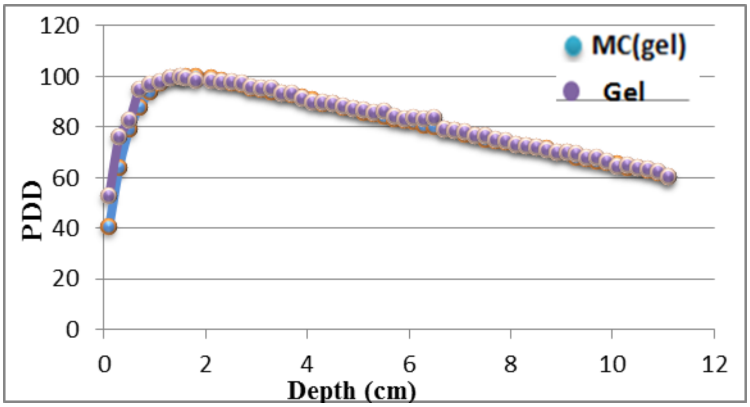

Figure 2. Percentage depth dose (PDD) from simulated MAGAT gel dosimetry and MAGAT gel measurements using 8 x 8 cm^2 field size

The beam profiles at 1.5 cm and 10 cm depths determined by simulated gel dosimetry, and gel measurements are shown in Figure 3. The penumbra at 1.5 cm depth of simulated gel dosimetry was found to be 5 mm on the left side of the central axis and 5 mm on the right side. The beam edge of simulated gel isodose curve was found to be 40 mm on the left of the central axis of the beam and 40 mm on the right side. The difference at 80% intensity of simulated gel dosimetry was found to be 1 mm (2.5%). The maximum disagreement of the dose value on the simulated isodose curve with that measured using gel dosimetry was found to be ±9%.The penumbra obtained at 10 cm depth for simulated gel dosimetry was found to be 7 mm on the left side of central axis and 6 mm on the right side. The beam edge was found 43 mm on the left of the central axis of the beam and 42 mm on right side. The difference at 80% intensity of simulated isodose curve was found to be 2 mm (5%). The maximum disagreement at 10 cm depth with gel dosimetry measurement was found to be ±9%.

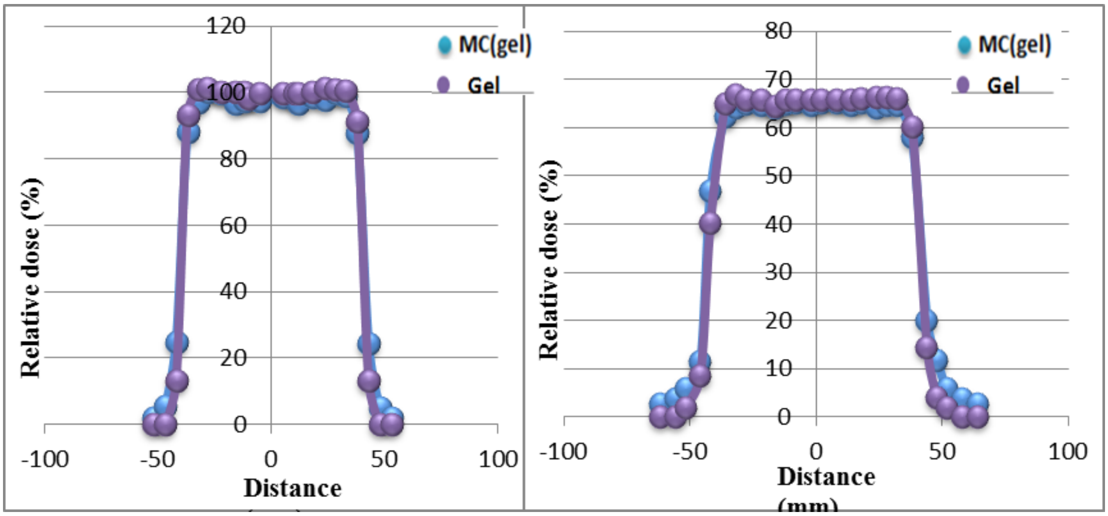

Figure 3. The beam profiles at 1.5 cm depth (left figure) and 10 cm depth (right figure) for the simulated MAGAT gel dosimetry and MAGAT gel measurements (8 x 8 cm^2 field size)

4. Conclusion

The PDD and isodose curves obtained using simulated gel dosimetry agreed very well with that measured using gel dosimetry. Therefore, the CT based MAGAT gel dosimeter has shown to be a useful method to measure dose of 6 MV photon beam.

References

[1] Aljamal, M., & Zakaria, A. (2014). Evaluation of CT based MAGAT gel dosimetry system for measuring 3D dose distribution, *Australian Journal of Basic and Applied Sciences, 8,* 538-542.

[2] Aljamal, M., & Zakaria, A. (2013). Monte Carlo Modeling of a Siemens Primus 6 MV Photon Beam Linear Accelerator. *Australian Journal of Basic and Applied Sciences, 7*, 340-346.

[3] Amin, M., Bonnett, D., & Horsfield, M. (2004). Normoxic polymer gels: are they magic?. *Journal of Physics: Conference Series*., *3,* 192-195.

[4] Baldock, C., De Deene, Y., Doran, S., Ibbott, G., Jirasek, A., Lepage, M., ... & Schreiner, L. J. (2010). Polymer gel dosimetry. *Physics in medicine and biology*,*55*(5), R1.

[5] Brindha, S., Venning, A. J., Hill, B., & Baldock, C. (2004). Experimental study of attenuation properties of normoxic polymer gel dosimeters. *Physics in medicine and biology*, *49*(20), N353.

[6] De Deene, Y., & De Wagter, C. (1999). Gel dosimetry in conformal radiotherapy: Validation, optimization and MR artifacts. In *Proceedings of the 1st International Workshop on Radiation Therapy Gel Dosimetry* (pp. 75-89). LJ Schreiner.

[7] De Deene, Y., Hurley, C., Venning, A., Vergote, K., Mather, M., Healy, B. J., & Baldock, C. (2002). A basic study of some normoxic polymer gel dosimeters.*Physics in Medicine and Biology*, *47*(19), 3441.

[8] Doran, S. J. (2009). The history and principles of chemical dosimetry for 3-D radiation fields: Gels, polymers and plastics. *Applied Radiation and Isotopes*,*67*(3), 393-398.

[9] Fong, P. M., Keil, D. C., Does, M. D., & Gore, J. C. (2001). Polymer gels for magnetic resonance imaging of radiation dose distributions at normal room atmosphere. *Physics in medicine and biology*, *46*(12), 3105.

[10] Gear, J. I., Flux, G. D., Charles-Edwards, E., Partridge, M., Cook, G., & Ott, R. J. (2006). The application of polymer gel dosimeters to dosimetry for targeted radionuclide therapy. *Physics in medicine and biology*, *51*(14), 3503.

[11] Gustavsson, H., Karlsson, A., Bäck, S. Å., Olsson, L. E., Haraldsson, P., Engström, P., & Nyström, H. (2003). MAGIC-type polymer gel for three-dimensional dosimetry: Intensity-modulated radiation therapy verification.*Medical physics*, *30*(6), 1264-1271.

[12] Kawrakow, I., E. Mainegra, D.W.O. E.-Hing, R.F., T., & W. B.R.B, (2009). The EGSnrc Code System: Monte Carlo Simulation of Electron and Photon Transport. Ionizing Radiation Standards, N.R.C.,Canada.

[13] Oldham, M., Siewerdsen, J. H., Shetty, A., & Jaffray, D. A. (2001). High resolution gel-dosimetry by optical-CT and MR scanning. *Medical physics*,*28*(7), 1436-1445.

[14] Salomons, G. J., Park, Y. S., McAuley, K. B., & Schreiner, L. J. (2002). Temperature increases associated with polymerization of irradiated PAG dosimeters. *Physics in medicine and biology*, *47*(9), 1435.

[15] De Deene, Y., Reynaert, N., & De Wagter, C. (2001). On the accuracy of monomer/polymer gel dosimetry in the proximity of a high-dose-rate 192Ir source. *Physics in medicine and biology*, *46*(11), 2801.