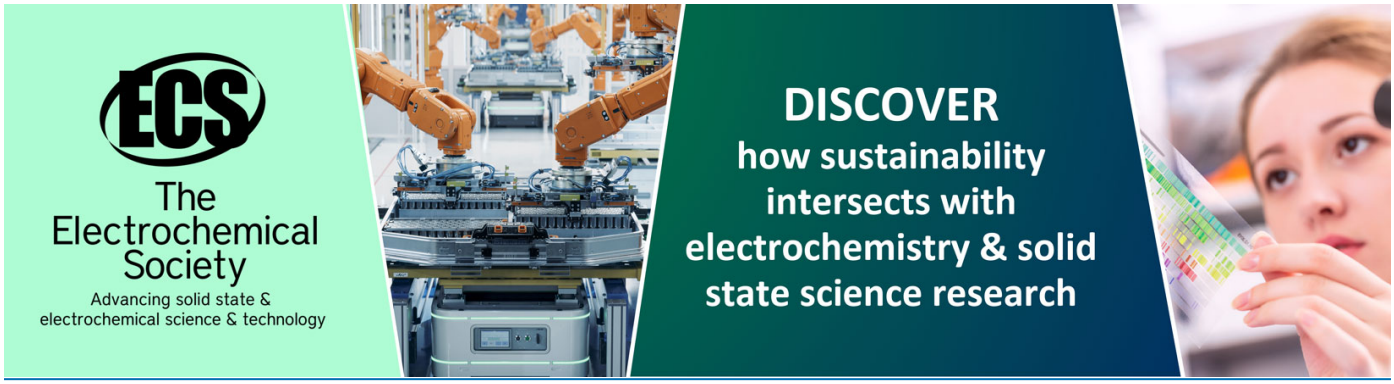
Application of MAGAT polymer gel dosimetry in breast balloon



Application of MAGAT polymer gel dosimetry in breast balloon

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Abstract. The purpose of this study is to characterize the response of MAGAT normoxic polymer gel for breast brachytherapy applications using two balloon applicators (MammoSite® and Contoura®) and verify the dose distribution with a commercial treatment planning system (BrachyVision® version 8.9.15). We present the fabrication, irradiation and readout of the gel used for the work described herein.

1. Introduction

There are several dosimetry techniques available to determine the radiation dose distribution delivered to the volume of interest during radiation therapy treatments. Each dosimetric tool has a unique advantage and simplicity of determination, along with their own strengths and weaknesses. Gel dosimetry is an inherent dosimetric method used to determine the 3D dose distribution of the absorbed dose in the medium [1, 2]. Different gels have been developed [3] and most recently normoxic polymer gels gains its own traction due to its simplicity of preparation under normal atmospheric condition and its high spatial resolution [4, 5]. A new type of gel composition called MAGAT, that is comprised of methacrylic acid, gelatin, tetrakis (hydroxymethyl) phosphonium chloride (THPC), was found to have desirable characteristics of normoxic polymer gels [6]. In particular, THPC was found to be an aggressive scavenger for dissolved oxygen, and exhibit good temporal stability and spatial resolution with an excellent R2 dose response and sensitivity (from MRI scanning).

2. Methods and Materials

2.1. Fabrication

The preparation of the MAGAT gel (Methaacrylic Gelatin And Tetrakis) in the laboratory used a table-top setup. The gel compositions consisted of a gelatin, methacrylic acid, and THPC. The percentage of the mixtures is summarized in Table 1.

Distilled water (430 g) were placed in a glass container and boiled using a hot plate. About 1/10th of gelatin (40 g) were then added to the boiling water and heated to 48 ºC to permit the gelatin to completely dissolve in the water. The mixture was then allowed to cool down, thus providing a clear solution. The temperature of the gel was constantly monitored using a thermometer and when the temperature felt below 35 ºC, 30 g of methacrylic acid (~99% titration, Sigma Aldrich) was added and mixed thoroughly. An additional 0.177 g of THPC (80% solution in water, Sigma Aldrich) was mixed to the solution which was again cooled for another 20 minutes. This clear gel solution was poured in six glass vials and into a larger (500 ml and 750 ml) glass phantom. Two glass containers, one with the

single lumen (MammoSite®) and the other with the mutli-lumen (Contura®) balloon were placed inside the gel container and inflated with a saline solution (35 ml) and a contrast agent (5 ml). The entire setup was placed properly at the center of the container. Finally, the bottles were wrapped with an aluminum foil and stored in a refrigerator with a set temperature of 4ºC. They were allowed to cool for 24 hours.

Table 1: Chemical composition of MAGAT polymer gel

1	Gelatin	8 % (40 g)
2	Methacrylic acid	6 % (30 g)
3	THPC (2mM)	0.177 g
4	Water	86% (430g)

2.2. Irradiation

The irradiation of the MAGAT gel was performed 24 hours after the preparation. Three sets of gels phantoms were prepared for this study: (i) calibration vials (ii) single lumen balloon catheter (MammoSite®) and (iii) Multi lumen balloon catheter (Contura®).

A Varian 2300ix linear accelerator was used to acquire the calibration data using the six vials. They were placed inside a perplex water phantom and positioned at the center of the field at 10 cm depth (FS= 10x10 cm^2, Figure 1(a). The theoretical dose requested varied from 0 (un-irradiated) to 7 Gy using 6 MV photon beams. The R2 dose response of the calibration vials are calculated based on the pixel value of the scanned MRI image is shown in Figure 1b.

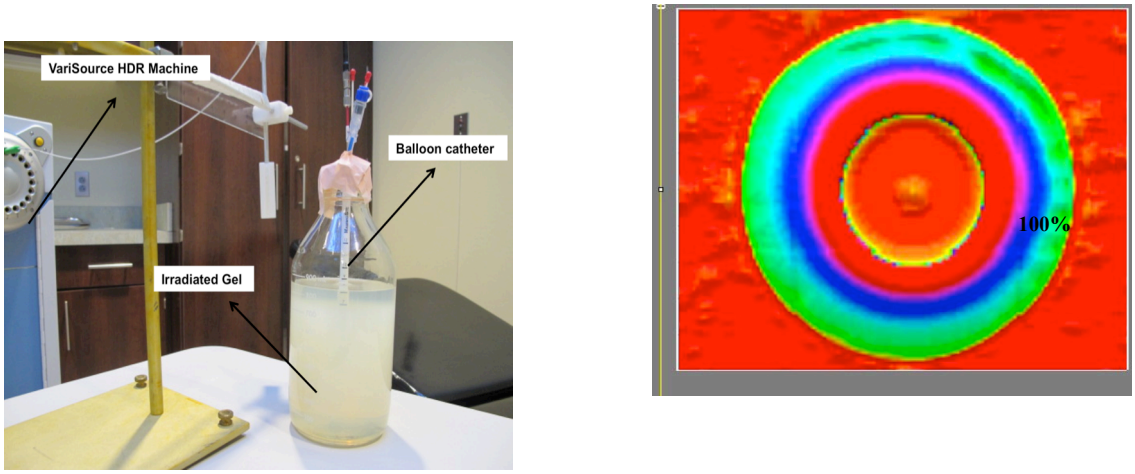
(a) (b)

Figure 1: (a) Calibration of vials using 6 MV X-ray beams (b) dose response of the MAGAT polymer gel for the calibration vials.

Two bottles of gel, one for the MammoSite® balloon and one for the Contura® balloon, were irradiated using the VariSource HDR brachytherapy afterloader machine (Figure 2a). A treatment plan was created for the two balloons using the Brachyvision® software version 8.9.15. The radiation dose of 340 cGy was prescribed at PTV (planning target volume), 1 cm from the surface of the balloon using a single dwell position. After irradiation, the gel containers were stored in a cool place at 18-20°C for the post polymerization and the gel to get stabilized.

2.3. Gel Readout

The MAGAT polymer gels used for this study were scanned using a 1.5 Tesla MRI scanner (Siemens Esperee Magnetron). The images were acquired under a spin echo sequence with a CPMG radio frequency pulse scheme. A total of 864 images were obtained with 32 echo images having the following parameter values: echo time spacing ΔTE = 22.4 ms, threshold ratio TR = 9970 ms and pixel size of 1 mm x 1mm with a slice thickness of 2 mm. Twenty seven sets of images were obtained and the scanned images were analyzed using a Matlab® code which uses the maximum likelihood estimator to estimate the R2 values .The decay constant R2 values (longitudinal relaxation rate=1/T2) were subsequently calculated from the MRI data using a maximum likelihood method from the exponential decay equation. The isodose distribution for the Mammosite® balloon using MAGAT gel is shown in figure 2b.



(a) (b)

Figure 2: (a) Balloon catheter irradiation (Ir-192 radioactive source) (b) Isodose distribution for MammoSite® balloon catheter (100% - 340 cGy)

3. Results and Discussion

The dose maps of the MammoSite® and Contura® balloons obtained from the MRI scanned data were compared to the treatment planning system: the gel dosimetry results provided are in very good agreement, less than 5%, with the TPS.

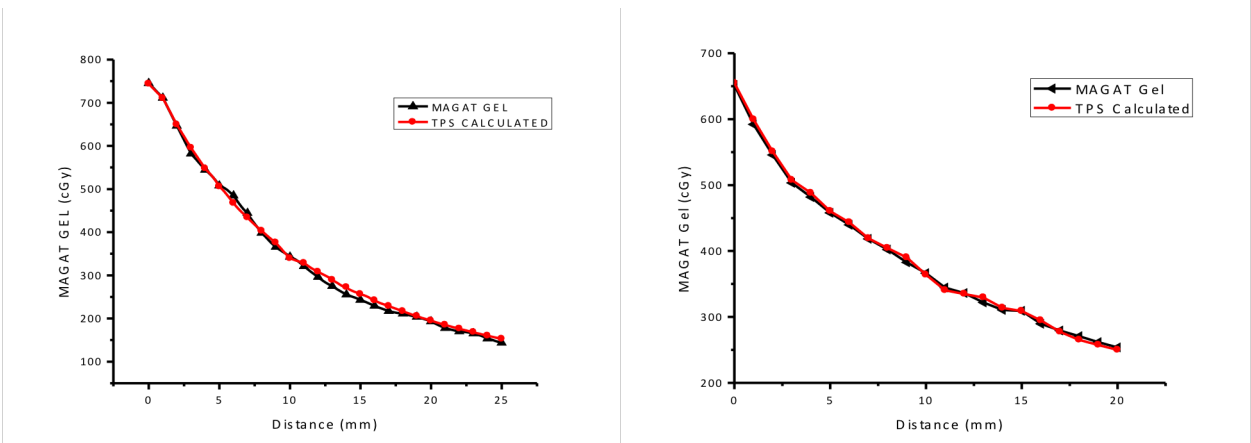


Figure 3: Comparison of MAGAT Polymer Gel with treatment planning system for (a) MammoSite® (b) Contura® balloon applicators

The MAGAT polymer gel was successfully used as a preliminary investigation for balloon brachytherapy applications to evaluate the 3D dose distribution of balloon catheters. It has been demonstrated that the MAGAT polymer gel can be used as a reliable tool for three dimensional dose verification of balloon brachytherapy techniques [7-9].

4. References

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