Characterizing Dose Distributions of Brachytherapy Sources Using Normoxic Gel

M.P. Heard, D.S. Followill and G.S. Ibbott

The University of texas M.D. Anderson Cancer Center, Houston, Texas

THE UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER

Abstract

Interstitial brachytherapy using ^{125}I and ^{103}Pd encapsulated sources has become a common treatment for prostate cancer patients resulting in an increased demand for these sources. In response to the growing demand, manufacturers have developed new models of ^{125}I and ^{103}Pd sources. The dose distributions of these low energy emitters are very sensitive to encapsulation geometry, self-absorption, and filtration, all of which vary with each manufacturer. As a result, the dose distribution of each seed must investigated as detailed in AAPM TG-43. This study investigated the dose distributions of three well-characterized seeds using a polymer gel. Each seed was placed in a gel via a catheter and a point 1cm away from the transverse axis was irradiated to the same dose. The gels were scanned using an optical scanner to obtain a matrix of optical densities. The dose rate dependence of the gel was investigated by comparing the response of the gels irradiated with ^{125}I of different activities. Having verified the dose distribution of the ^{125}I seed with previous data, the response of the gel irradiated with ^{103}Pd was compared to a gel irradiated with ^{125}I to investigate the energy dependence of the gel. The radial dose function (TG-43 parameter) for these seeds was determined from the measured data.

Background

Polymer gels are made up of water, gelatin, and acrylic monomers that polymerize when exposed to radiation. Ionizing radiation produces free radicals within the gel and these in turn lead to the formation of polymer microparticles which remain attached or entangled with the gelatin. The spatial distribution of the polymer is representative of the dose distribution of the radiation (Maryanski et al 1994). Polymer gels were first introduced by Maryanski et al and are known as BANG® gel. The gel's name is an acronym for the chemical composition: bis, acrylamide, nitrogen and gelatin. Many studies have been done using BANG® gel and it has been proven to be a useful dosimeter. However, the one drawback is that BANG® gels are very sensitive to oxygen, thus requiring hypoxic condition during their manufacture, storage, and use.

The oxygen sensitivity of BANG® gels has resulted in the search for a gel that is insensitive to normal environmental conditions. Fong et al. have developed a normoxic gel called MAGIC gels. The MAGIC gel is composed of gelatin, methacrylic acid, ascorbic acid, copper sulfate, and hydroquinone. The copper sulfate and ascorbic acid utilizes oxygen to make free radicals which in turn initiate polymerization (Fong et al 2001). This distinguishes MAGIC gels from previous polymer gels whose response is inhibited by oxygen.

The polymerization of the gels, which represents the dose distribution, can be imaged using optical scanning methods. The optical scanner is modeled after a first generation x-ray CT so that the gel is scanned in a translate-rotate fashion. The optical scanner uses a He-Ne laser to scan the gel. Photodiode detectors are used to measure the attenuation of the beam as it passes through the gel. An image can then be reconstructed using filtered back projection to generate a 3 dimensional matrix of optical densities that are proportional to dose.

Purpose

The purpose of this project is to characterize the dose distributions of ^{125}I and ^{103}Pd seeds using a normoxic gel. This project will be helpful in further understanding gel characteristics as well as providing a framework for future source characterization using normoxic gels. Gel dosimetry provides 3D information so that all of the dosimetric parameters required to calculate absorbed dose can be determined for a source in a single irradiation.

Materials and Methods

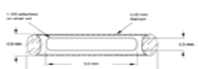

Figure 1. *Amersham 6711 (^{125}I)*

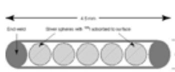

Figure 2. *Imagyn IS-12501 (^{125}I)*

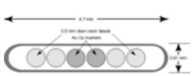

Figure 3. *NASI MED3633 (^{103}Pd)*

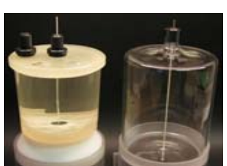

Figure 4. *Glass and Barex Canisters used for irradiation. Barex Catheter is placed in the middle to allow placement of the source inside the gel while preventing oxygen contamination*

A Magic gel containing 3% methacrylic acid was made for the comparison of the 6711 seed to the Imagyn seed. A 9% MAGIC gel was made for the comparison of the 6711 seed to the NASI ^{103}Pd. The time of irradiation was calculated to deliver the same dose to each gel at 1 cm along the transverse axis of the seed (3% and 9% gels were irradiated to different doses)

The dose rate at point (r,θ) was calculated according to TG-43 two dimensional formalism:

$$\dot{D}(r,\theta)=S_k \wedge [G(r,\theta)/G(r_0,\theta_0)]g(r)F(r,\theta)$$

The dose at point (r,❑) was calculated using the following formula:

$$D(r,\theta)=\dot{D}(r,\theta)T_{av}[1-e^{-T/T_{av}}]$$

where T = time of irradiation and $T_{av} = 1.44T_{1/2}$

After irradiation, the catheter was removed from the gel and the void was filled unirradiated with gel. The gels were imaged using an optical CT scanner (Maryanski et al 1996) and images were analyzed using a MATLAB® program written for this study.

Figure 5. *Picture of the Optical CT scanner used in this study*

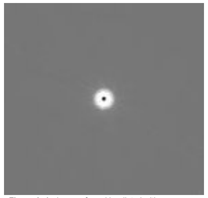

Figure 6. *An image of a gel irradiated with a brachytherapy source. The black dot in the center is the location of the source.*

A program written in MATLAB® imports the image, finds the location of the seed in the plane, and obtains the average pixel values at specified distances from the source. A dose response curve was determined from measurements of dose around the 6711 seed. The optical density maps of the Imagyn and NASI seeds were converted to dose using the 6711 dose response curve. The radial dose function for each was then determined.

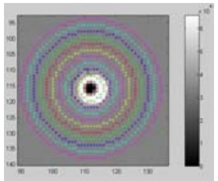

Figure 7. *Program selecting pixels at specified distances from the source location.*

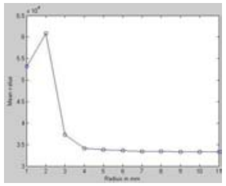

Figure 8. *Output of the program, showing mean pixel value vs. distance from source*

Results

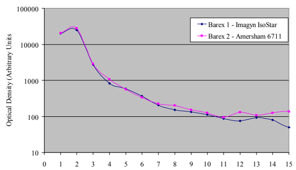

Figure 9. *Comparison of measurements with the 3% gel irradiated with 6711 and Imagyn seeds*

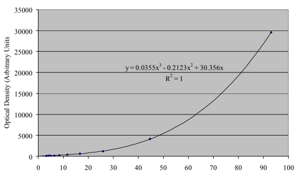

Figure 10. *Dose response curve of the 3% gel irradiated with a 6711 seed*

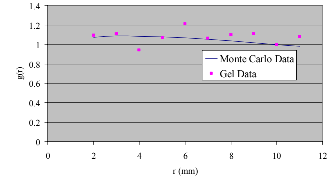

Figure 11. *Radial Dose Function of the Imagyn seed from monte carlo calculation and gel measurements*

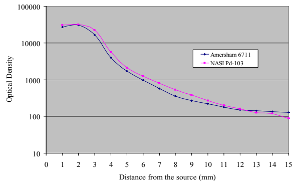

Figure 12. *Comparison of measurements with the 9% gel irradiated with 6711 and NASI MED3633 seeds*

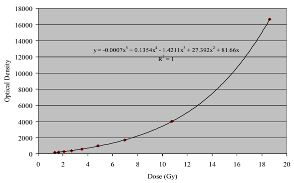

Figure 13. *Dose response curve of 9% gel irradiated with a 6711 seed*

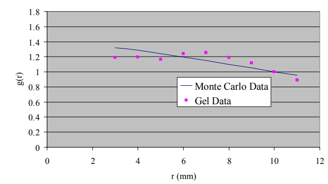

Figure 14. *Radial Dose Function of the NASI MED3633 seed from monte carlo calculation and gel measurements*

Discussion

The uncertainties of the measurements were large due to the large variation in pixel value at each the specified distances from the source (These variations were over 100% for the 3% gel). The variation in OD is the dominant source of error in the determination of the radial dose function. The 9% gel showed lower uncertainty, possibly because it is a more sensitive gel. Although the uncertainties are large, the maximum difference between the measured radial dose function and the published data is 14%

Future Works

- Replace 1mm ID barex tubing with a larger ID tubing and obtain distrubution information at larger distances
- Find mixture of gel which results in large range and gives good SNR
- Obtain 3D data from a single irradiation and obtain all TG-43 parameters
- Investigate more sources and compare with published data
- Conduct reproducibility evaluation

References

1) Fong, P. M., Keil D. C., Does, M. D., and Gore, J. C., "Polymer gels for magnetic resonance imaging of radiation dose distributions at normal room atmosphere," Phys. Med. Biol. 46, 3105-3113 (2001).
2) Maryanski, M. J., et. al., "Magnetic resonance imaging of radiation dose distributions using a polymer gel dosimeter," Phys. Med. Biol. 39, 1437-1455 (1994).
3) Maryanski, M. J., et. al., "Radiation dose distributions in three dimensions from tomographic optical density scanning of polymer gels: II. Optical properties of the BANG polymer gel," Phys. Med. Biol. 39, 1437-1455 (1994).