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Cone Beam Optical CT Investigation on Tissue Equivalent Normoxic Polymer Gel Dosimeter

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Abstract. A potential method has emerged in the form of water-equivalent "3D gel dosimetry" using optical computed-tomography (optical-CT) which enables accurate, high resolution, 3D measurement of dose distributions associated with modern radiation treatments.. Optical Cone Beam CT (CBCT) scanner plays a major role for Gel dosimeter readout and clinical radiation therapy as 3-Dimensional Radiation Dosimetry. The normoxic PAGAT (Polyacrylamide Gelatin and Tetrakis) gel is used as a dosimeter for this cone beam CT analysis due to its tissue equivalent behaviour. Applying a uniform background subtraction of open field intensity resulted in cone beam CT reconstructed attenuation coefficient for a PAGAT Gel Dosimeter.

1. Introduction

Modern radiotherapy techniques such as stereotactic radiotherapy (SRT) stereotactic radiosurgery (SRS), three dimensional conformal radiotherapy (3DCRT) and intensity modulated radiation therapy (IMRT) aim to deliver a high dose to the tumour while sparing the surrounding normal healthy tissues. As a result of these complicated treatment techniques there is a need for a 3- dimensional (3D) dose verification system. However, currently available dosimeters such as ion chambers, diodes, thermo luminescent dosimeters and films are limited to point (or) planar measurement. Multiple measurements are required for obtaining the 3-dimensional dose distribution using the above dosimeters. Gel dosimetry attempts to meet the requirements of 3D radiation dose distribution. Gel dosimetry is tissue equivalent [1] and it acts as a gel phantom as well as gel dosimeter so there is no need for dose perturbation correction. Optical Computed Tomography provides an inexpensive and easy to use alternative imaging modality [1-5]. However, optical computed tomography approaches introduce novel challenges because of the inherent complications from the index of refraction matching at interfaces, multiple scattering in polymer systems [3, 4, and 6]. Improvements in radiotherapy treatments based on an increased complexity of the treatment approach require accurate determination of the absorbed dose. Computer calculations have frequently been used to estimate three-dimensional dose distributions in complex geometries and therefore it becomes important to validate these by accurate three-dimensional measurements. As the dose is delivered from multiple directions, the phantom must represent a three dimensional body [5]. Due to its flexibility, tissue equivalence, ability to act as both the detector and phantom and provide spatial distribution of absorbed dose, gel dosimetry offers the potential to provide the desired dosimetric environment for complex radiotherapy delivery techniques. To date, MR scanning, which is expensive and can be susceptible to subtle sources of error [3] has been utilized as the main readout system for gel dosimetry. Gore *et al* [2] proposed optical CT scanning of PAG gels, an approach analogous to first-

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generation x-ray CT with the x-ray source replaced by a visible laser and the x-ray detector replaced with a light-sensitive photodiode. Kelly [4] demonstrated this technique for ferrous benzoic xylenol (FBX) gel dosimeter by applying Cone Beam CT imaging principle used in x-ray imaging to optical CT using CCD array detector. In this paper we present some initial investigations of the use of a Vista Cone Beam Optical CT scanner (Modus Medical Devices Inc., London, Canada) in relation with normoxic PAGAT Gel Dosimeter. This approach of recording transmission images of the gel is the inverse of x-ray cone beam CT if you consider only the rays, which contribute to image formation [7].

2. Materials and Method

2.1. Gel Preparation

The conventional polymer gel dosimeter used in this study was the normoxic ''PAGAT'' gel described elsewhere (Venning et al., Hill et al and Brindha et al.,) [8-10] and was prepared under normal atmospheric conditions. The PAGAT polymer gel consisted of 3.5% (w/w) N, N-methylene-bis-acrylamide (BIS), 3.5% (w/w) acrylamide, 5% (w/w) gelatin, 89% triple distilled water and 10mM tetrakis hydroxymethyl phosphonium chloride (THP) as antioxidant. The gel preparation was carried out as follows: 5% gelatin was added to the magnetic stirred glass flask containing 89% of triple distilled water and allowed to swell for 10–15 min. Then the gelatin solution was heated to the temperature of 50 ^{o}C for complete dissolution of the gelatin. After obtaining the clear gelatin solution 3.5% BIS and 3.5% Acrylamide were added and stirred continuously until the mixture was dissolved homogeneously. The antioxidant 10 mM THP was added to the solution under stirring just before transferring the gel into the Polyethylene Teraphthalate cylindrical jars of size 10 cm diameter and 13 cm long. All the polyethylene teraphthalate cylindrical jars containing the PAGAT gel were sealed properly to avoid the further diffusion of oxygen and were kept in a refrigerator for one full night for gelling.

2.2. Gel Irradiation

To evaluate the dose response of polymer gel to gamma radiations, the polymer gel dosimeters were irradiated after the complete gellation. The center of the phantom was aligned with the crosshairs of the treatment field. The polymer gel dosimeters were irradiated with a direct square field size of 5 x 5 cm^2 for gamma rays using Co-60 source with a dose of 12 Gy. The source-to-surface distance (SSD) was 100 cm. One gel dosimeter was kept unirradiated for background subtraction. The irradiated gel dosimeters were left in a refrigerator for one day before imaging to allow the complete post irradiation polymerization.

2.3. Cone Beam Optical CT scanner

CT images were obtained with the Vista Optical Cone Beam CT scanner. The scanner uses 630 or 590 nm LED array to provide illumination and the projection data are acquired with a 1024 x 768 pixels, 10-bit monochrome CCD camera. The acquisition and reconstruction time using the Feldkamp back projection algorithm for the above mentioned gel dosimeter takes around 10 minutes. For all runs, reference scans were taken immediately before irradiation and dosimetry scans were performed 24 hours after irradiation to avoid temporal instabilities as the radiation-induced polymerization proceeded. The data shown in this work were taken at 590 nm (yellow light) and reconstructed images had a voxel resolution of 0.5 mm. Data analysis was performed with in-house code developed in Mat Lab (Math works, Natwick, USA).

The post irradiated gel phantom or dosimeter can be kept in a place for imaging which consists of a uniform LED light source of 590 nm that could provide parallel rays, A Perspex made aquarium of size 15 cm^3 of wall thickness of 5 mm on the light transmission regions with a stepper motor holder positioned upwards to rotate the gel phantom to 360 degrees, and a CCD camera an imaging device to image the gel phantom are the three main parts required for the construction of an optical cone beam CT scanner. The gel phantom was rotated using a stepper connected at the top of the phantom holder.

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The motion of the stepper motor was controlled with the help of a Personal Computer. The Vista Cone Beam Optical CT scanner used for this work is shown in figure 1.

Figure 1. Vista Optical Cone Beam CT Scanner.

3. Results and Discussion

Due to irradiation, polymerization occurs on the gel dosimeters. Hence the monomers presented in the gel are converted in to polymers. The pre-irradiation images were subtracted from the post-irradiation scans and subtracted images were analysed. The pre and post irradiation image data set of 340 frames in 360^0 of 1024 x 768 pixels were loaded for reconstruction. The reconstruction has been done using

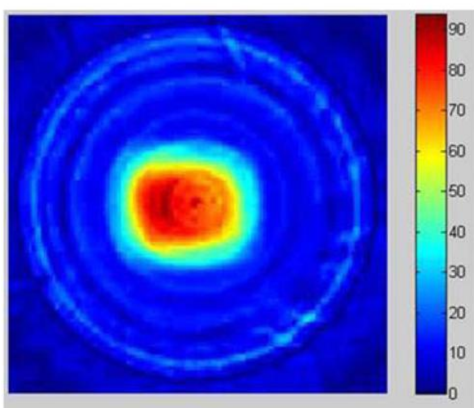

Figure 2. 2D Subtracted Image with colour bar of CT Reconstructed Slices of Post irradiated gel at depth of 3cm.

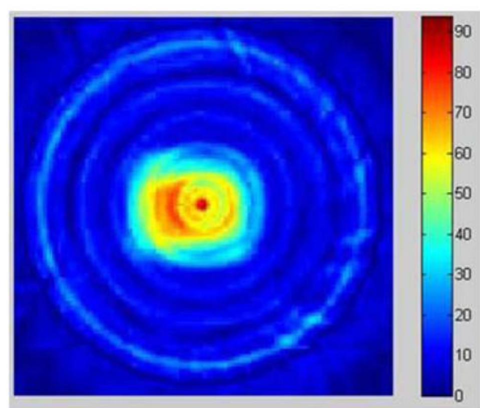

Figure 3. 2D Subtracted Image with colour bar of CT Reconstructed Slices of Post irradiated gel at depth of 6cm.

the Feldkamp filtered back projection algorithm implemented in Vista Scan software and slice by slice subtracted image of the post irradiated slices has been obtained in 3 cm and 6 cm depths shown in figure 2 and figure 3. Data analysis like getting Dose profile in the reconstructed slices and subtraction of post irradiated images from pre irradiated images was performed with in-house code developed in Mat Lab (Math works, Natwick, USA). Figure 4 represents the dose profile at 3cm depth of the post irradiated gel phantom whereas figure 5 represents the dose profile at 6cm depth. In the figures

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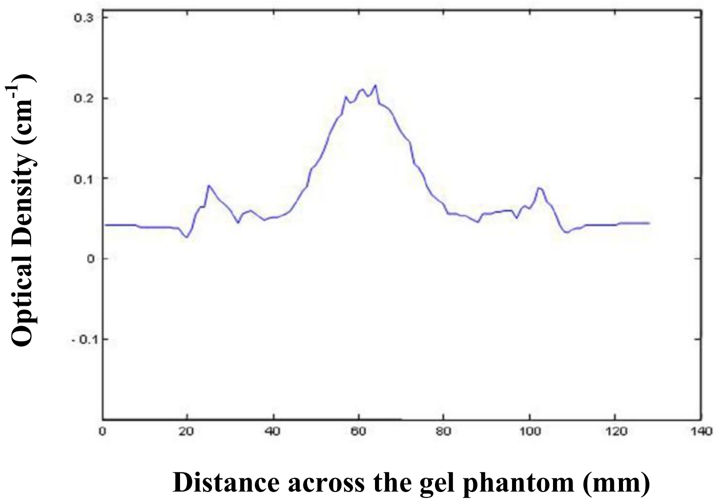

Figure 4. Dose Profile for Post irradiated gel slice at 3cm depth.

mentioned above, the distance across the gel phantom has been plotted in the x axis and the optical density (OD) has been plotted in the y axis.

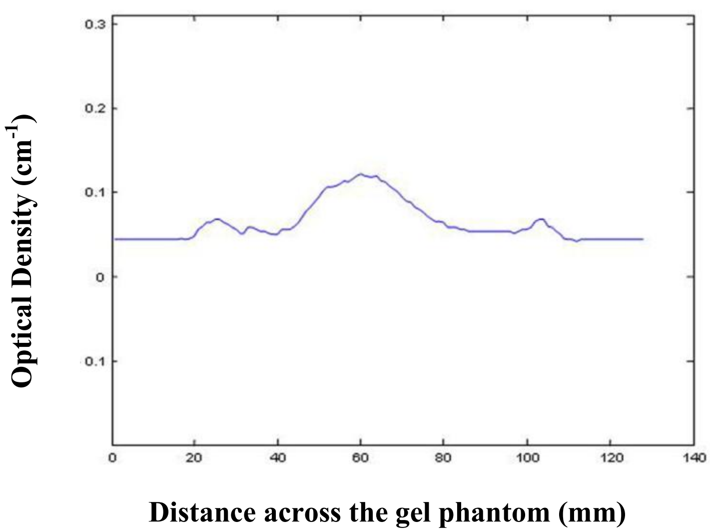

Figure 5. Dose Profile for Post irradiated gel slice at 6cm depth.

4. Conclusions

The experience with Vista Optical Cone Beam CT scanner of dual LED sources and a CCD camera has been performed with the tissue equivalent normoxic PAGAT Gel Phantom. The profile plots for the reconstructed slices after subtracting with the pre irradiated slice were acquired using in-house code developed in Matlab. The CT reconstructed images for the corresponding slices suggested that it is one of the cheapest and easiest methods for mapping gel dose distribution. Corresponding Iso dose distribution for the post irradiated gel phantom can be obtained by further enhancing the Matlab software. Investigating the feasibility of using Optical CT Gel Dosimetry for the verification of IMRT, SRS, SRT and comparing this Vista Optical CT results with pre-existing 3D commercially available planning software will be the future studies.

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References
[1] Maryanski M J, Zastavker Y Z, Gore J C 1996 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.* **41** 2705–2717
[2] Gore J C, Ranade M, Maryanski M J, Schulz R J 1996 Radiation dose distributions in three dimensions from tomographic optical density scanning of polymer gels: I Development of an optical scanner *Phys Med Biol.* **41** 2695–2704
[3] Oldham M, Siewerdsen J H, Kumar S, Wong J, Jaffray D A 2003 Optical-CT gel-dosimetry I: Basic investigations *Med Phys.* **30** 623–634
[4] Kelly R G, Jordan K J, Battista J J 1998 Optical CT reconstruction of 3 D dose distributions using the ferrous-benzoic-xylenol (FBX) gel dosimeter *Med Phys.* **25** 1741–1750
[5] Kron T 2001 Radiation therapy requirements: what do we expect from gel-dosimetry? *Proc 2nd Int. Conf. Radiotherapy Gel Dosimetry.* 2–9
[6] Doran S J, Koerkamp K K, Bero M A, Jenneson P, Morton E J, Gilboy W B 2001 A CCD based optical CT scanner for high-resolution 3D imaging of radiation dose distributions: equipment specifications, optical simulations and preliminary results *Phys Med Biol.* **46** 3191-3213
[7] Jordan K J, Pajak T M, Pionteck C, Battista J J 2001 Optical cone beam tomography with low pressure sodium light *Proc 2nd Int Conf Radiotherapy Gel Dosimetry.* 172–174
[8] Venning A, Hill B, Brindha S, Healy B J, Baldock C 2005 Investigation of PAGAT Polymer gel dosimeter using magnetic resonance imaging *Phys Med Biol.* **50** 3875-3888
[9] Hill B, Venning A, Baldock C 2005 The dose response of normoxic polymer gel dosimeters measured using X-ray CT *Brit J Radiol.* **78** 623-630
[10] Brindha S, Paul B R, Baldock C 2006 Optimization of imaging protocol of an X-Ray CT scanner for evaluation of normoxic polymer gel dosimeters *J Med. Phys.* **31** 72-77