Initial experience with a commercial cone beam optical CT unit for polymer gel dosimetry I: Optical dosimetry issues

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1. Introduction
Treatment validation of conformal plans is becoming a very important part of radiation therapy. Soon after its inception, gel dosimetry was shown to have a great potential for 3D dosimetry, particularly after the development of more spatially stable polymer-based dosimeters. However, despite its promise, gel dosimetry has not come into widespread clinical use, in part because of limited access to imaging modalities (particularly MRI) for dose readout. Optical Computed Tomography provides an inexpensive and easy-to-use alternative imaging modality [1-4]. However, optical CT approaches introduce novel challenges because of the inherent complications from index of refraction matching at interfaces, multiple scattering in polymer systems, etc. [2-4]. In this paper we present some initial investigations of the use of a Vista cone beam optical CT unit (Modus Medical Devices Inc., London, Canada) in conjunction with various polymer gel dosimeters.

2. Materials and Methods
CT images were obtained with the Vista Optical CT scanner. The scanner uses 630 or 590 nm LEDs to provide illumination and projection data are acquired with a 1024 x 768 pixels, 8-bit monochrome CCD camera. The acquisition and reconstruction time (340 frames in 360\degree, Feldkamp backprojection) for a 10 cm cube with 1 mm voxels takes \sim 15 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 630 nm and reconstructed images had a voxel resolution of 0.56 mm. Data analysis was performed with in-house code developed in MatLab (Mathworks, Natwick, USA).

N-isopropylacrylamide (NIPAM) or Diacetone Acrylamide (DAAM) based polymer gels (accompanying paper in this proceedings and ref. [5]) and conventional PAGAT were used in this study. The gel dosimeters consisted of gelatin (5 wt\%), crosslinker bisacrylamide (3 wt\%), monomer (3 wt\%) and 10 mM antioxidant tetrakis hydroxymethyl phosphonium chloride. All chemicals were from Sigma Aldrich or ICN Biomedicals Inc. Gels were poured into 800 ml polyethylene teraphthalate (PET) bottles for imaging and were irradiated using a T780 Cobalt-60 unit (MDS Nordion, Kanata, Canada) approximately 24 hours post-manufacture using large open beams or 1x1 cm\textsuperscript{2} pencil beams.
3. Results and Discussion
Typical image cross sections through select planes of irradiated phantoms are shown in Figure 1 and 2. As expected from the multiple scattering conditions in polymer systems, gels irradiated to uniform but high doses with significant opacity exhibit cupping in CT numbers as one crosses the phantom. Gels that are irradiated with distributions that preserve transparency throughout most of the phantom (e.g., conformal distributions or pencil beam irradiations as shown in Figure 2) show well behaved dose response and calibration curves can be obtained. The data in the calibration curve on the right of Figure 2 are taken from the different pencil beams on the left. The CT data show good reproducibility over multiple scans of the same phantom, and in fact, irradiations can be added at different times and data integrity is preserved (see Figure 3).

**Figure 1.** Vertical cross section of a uniformly irradiated NIPAM dosimeter. The figure on the right shows the CT numbers along the profiles of the cross section that is indicated in white, but for two different doses.

**Figure 2.** Slices of the DAAM dosimeter taken by the optical CT scanner. Profiles to obtain the calibration curves were taken through the center of the pencil beams as shown on the left image. They were also taken at different depths within the gel to cover a greater range of doses as shown on the image in the center. The graph on the right is a calibration curve obtained from the data in the other figures.
To investigate the effect of gel opacity on the dose calibration curves, test tubes NIPAM gel were irradiated to known doses and then scanned in the centre of the system with the surrounding water doped to various levels with milk as a scattering medium. Figure 4 illustrates that the dose calibration depends on the opacity of the media surrounding the test tube. However, the shift in the calibration curves can be controlled if opacity of the medium is kept low.

**Figure 3.** On the left, a profile of NIPAM gel irradiated with a uniform flood field and then one week later with pencil beams from the top (combining the conditions of Figs. 1 and 2). Edge effects are seen at the boundary of the phantom bottle, the times listed are after final irradiation.

**Figure 4.** The calibration curves for five test tubes of NIPAM gel irradiated from 0 to 50 Gy. The test tubes were placed in 3 different water-milk mixtures of varying opacity during the cone beam imaging.

4. Conclusions
At present, the Vista cone beam optical computed tomography system is providing promising results for gel dosimetry. Well behaved and reproducible data relating measured optical CT numbers with dose are obtained and calibration data appropriate to scatter conditions can be obtained. It is clear, however, that appropriate irradiation conditions at low dose to minimize scatter must be maintained.
for quality dosimetry. Under these conditions clinical utility is well indicated (see accompanying paper Part II in this issue).

5. Acknowledgments
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6. References
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