A simple optical cone beam CT set-up for gel ‘readout’

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1. Introduction

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 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 [1]. 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. Of the different methods investigated for scanning both ferrous and polymer gels, magnetic resonance (MR) imaging and optical computer-tomography (CT) have been extensively used as imaging techniques for ferrous gel. To date, MR scanning, which is expensive and can be susceptible to subtle sources of error [2] has been utilized as the main readout system for gel dosimetry. Gore et al [3] proposed optical CT scanning of PAG gels, an approach analogous to first-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. In spite of the three dimensional nature of the optical CT scanning of the gel it is worth pointing out that to date most work has only used two-dimensional evaluations of the three-dimensional data set available mainly due to the long scanning time required with this first generation optical CT scanning technique. Recently this limitation has been overcome by applying the cone beam CT imaging principle used in x-ray imaging to optical CT using CCD array detector [4]. In this study we have attempted to setup a simple optical cone beam CT using the geometry used by Wolodzko et al and Jordan et al [5] using an Intel webcam. 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 [5]. This simple optical cone beam CT could be setup with minimum cost and could be used to demonstrate the principle of optical CT for teaching and if further investigated could be a potential optical readout device for gel dosimetry.

2. Materials and methods

A uniform light source that could provide parallel rays, an aquarium with a turntable to rotate the gel to 360 degrees, and an imaging device to image the gel are the three main parts required for the construction of an optical cone beam CT scanner. We constructed a light source with nine 15 watt
light bulbs fixed in a box to provide a uniform source of white light. This was filtered using a green filter to provide a near green light source.

An aquarium of size 20 cm³ was constructed using Perspex with wall thickness of 3 mm on the light transmission sides. A turntable with angular graduation was fixed in the aquarium. This turntable was rotated using a 4 pole stepper motor controlled with a PC. Reduction gears were used to ensure one-degree rotation for every pulse sent to the stepper motor.

**Figure 1.** Set-up for optical cone beam CT with a webcam.

In this study we used Fe gel prepared by adding 4% gelatin to 50 mM H₂SO₄, 0.5 mM ferrous ammonium sulphate and 0.05 mM xylenol orange. The gel was prepared in a thin walled polystyrene cylinder of diameter 10 cm. The gel images were acquired with an Intel webcam with a resolution of 240 x 320 pixels. The webcam exposure was fixed to a predetermined level to obtain constant exposure for all the images. The optical cone beam CT set-up used is shown in figure 1. Initially a pre-irradiation scan of the gel phantom was obtained. Transmission images of the gel were acquired at every one-degree for 180 degrees. The gel was then irradiated with a cobalt beam of size 5 x 5 cm² and post irradiation images were acquired in a similar way as that of the pre-irradiation scan.

### 3. Results

The images acquired with this webcam for un-irradiated and irradiated gels are shown in figure 2. 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 180 images of size 240 x 320 were loaded into a 3 D array using MATLAB (The MathWorks, Natick, MA). For reconstruction of each slice an array was generated using green pixel values of the image data set. The pre and post irradiation profiles of the transmission data at the mid slice of the gel were compared in figure 2c. Slice reconstruction from the image data set was performed using the Inverse RADON transformation algorithm implemented in MATLAB.
Figure 2. (a) webcam image of the un-irradiated gel in the aquarium, (b) image of the irradiated gel and (c) transmission profiles of irradiated and unirradiated gel.

The reconstruction was performed with the transmission data for un-irradiated gel, irradiated gel and subtracted data set of irradiated from unirradiated and the reconstructed images are shown in figure 3a, b and c respectively. From the geometry of the setup of the camera and the aquarium, the cone angle was 14 deg and the resorting of the data to convert to parallel beam data set has not been performed.

Figure 3. CT Reconstructed images of gel (a) pre-irradiation, (b) post-irradiation and (c) subtracted image.

4. Conclusion

A simple optical cone beam CT set up has been demonstrated with an ordinary light and a webcam. The profile plots of the images acquired and the CT reconstructed images suggest that it is possible to use this for mapping gel dose distribution. However the small linear response range of the data acquired (0–255) is a major limitation of using the conventional camera as mentioned by Jordan et al [5]. Replacing the webcam with a scientific grade CCD camera will enhance the accuracy of measurement.
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