A preliminary study on the use of FX-Glycine gel and an in-house optical cone beam CT readout for IMRT and RapidArc verification

Paul B Ravindran, Ebenezer Suman Babu S, Winfred Michael Raj and Amalan S
Medical Physics Division, Department of Radiation Oncology, Christian Medical College, Vellore, India
Email: paul@cmcvellore.ac.in

Abstract. The radiochromic FX gel with Optical CT readout has been investigated by several authors and has shown promising results for 3D dosimetry. One of the applications of the gel dosimeters is their use in 3D dose verification for IMRT and RapidArc quality assurance. Though polymer gel has been used successfully for clinical dose verification, the use of FX gel for clinical dose verification with optical cone beam CT needs further validation. In this work, we have used FX gel and an in-house optical readout system for gamma analysis between the dose matrices of measured dose distribution and a treatment planning system (TPS) calculated dose distribution for a few test cases.

1. Introduction
High precision complex radiotherapy dose delivery techniques have considerably increased the interest in 3D dosimetry. A few dosimetry systems such as the ArcCHECK, Delta4 and Octavius 4D provide dose distribution in 3D, by measuring dose in 2D and reconstructing to 3D geometry. Several investigators have developed gel dosimeters that provide true 3D dose distribution [1-18]. Of the gel dosimeter, the FX gels have the advantages of easy preparation, good spatial resolution, sensitivity, linearity of dose response and tissue equivalence [19, 20]. Moreover, the radio-chromic nature of the FX gel enables the use of less expensive optical method for reading the dose embedded in the gel matrix. However, FX gel suffers from ion diffusion which destroys the spatial dose information rather quickly after the irradiation, thus requiring reading of the gel soon after the formation of ferric ions post irradiation [21].

In this work we have performed a preliminary study on the use of FX-Glycine gel with the in-house optical cone beam readout system for quality assurance of IMRT and RapidArc irradiation.

2. Materials and Methods
In this work the FX gels prepared were irradiated with plans developed using Eclipse planning system for IMRT and RapiArc plans with 6MV beams. The gel was irradiated on Clinac 2100C/D unit that has millennium multi-leaf collimator and on board imager.
2.1. The FX Gel

The FX gel used in this study was prepared with 240 bloom gelatine (Sigma), Ferrous Ammonium Sulphate (S D Fine-Chem Limited), xylenol orange (Sigma-Aldrich) and sulfuric acid with glycine (0.3mM) anti-oxidant added to reduce the rate of diffusion as suggested in our earlier paper [22]. The characteristics of this gel including its lower diffusion rate have been studied [22]. Gels were prepared in cylindrical transparent containers suitable for optical scanning. For each batch, two bottles of gels were prepared, one for dosimetry, and the other for calibration.

2.2. Optical Cone Beam CT

The optical cone beam CT (OCT) used in this study, is an upgraded version of our in-house optical CT scanner [23]. In the upgraded version, the control and the reconstruction software have been developed in Visual C Sharp. The projection images from the camera are obtained for each degree for 194 degrees. The reconstruction is performed with FDK reconstruction code originally developed for cone beam reconstruction of MV CBCT images [24]. This code has been converted to CUDA so as to work on a Graphic Processor Unit (GPU), thus enabling fast reconstruction. A pre-scan is performed prior to irradiation and the post scan is performed in about 30 minutes after irradiation. The reading of the irradiated gel and the reconstruction takes less than three minutes thus allowing minimal degradation of the gel matrix due to diffusion during scanning. The new version of our reconstruction software also has provisions to apply various filters such as ramp, Butterworth, Gaussian, Hanning, Hamming and Parzen, Shepp-Logan and Metz. In this work, all the reconstructions were performed with Ramp and Hamming filters.

2.3 Verisoft software

The Medphysto software provided by PTW has a module ‘Verisoft’ that enables calibration of the detector array, acquisition of dose distribution in 2D as well as in 3D and gamma evaluation of the comparison of measured or calculated dose distribution. The software enables 2D and 3D gamma comparison based on the Gamma Index method suggested by Daniel A low et al [25]. The Optical Cone beam CT data was converted RT dicom dose file so that it could be read by the Verisoft for gamma evaluation.

2.4 Gel irradiation

The gel phantoms were prepared as per the method described in section 2.1. For gel irradiation, a few test plans were created with the Eclipse planning system on the CT data set of the Gel phantom. The pre-scan of the gel was performed prior to irradiation. For calibration, the gel phantom was irradiated with four 2 cm x 2 cm fields to deliver 100, 200, 300 and 400 cGy to the mid plane of the gel phantom. A plan was created with similar beams on the Eclipse planning system and the dose at the mid plane was determined for calibration against the optical attenuation coefficient.

3. Results and Discussion

3.1 Calibration

The plan generated with the Eclipse planning system on the CT data set of the gel phantom for the calibration of the gel and the optical CT readout of the irradiated gel are shown in figures 1a & b. The optical density to dose relationship was obtained.

3.2 Analysis of gel dosimetry

A couple of RapidArc test plans were generated with the Eclipse planning system with a ‘C’ shaped and a butterfly shaped PTVs. Verification plans were also generated on the gel phantom for patient plans having PTV smaller than 5cm. The gels were irradiated as per the plan and read with optical CT. Both 2D and 3D gamma analysis between the dose matrices of measured dose distribution and treatment...
planning system (TPS) calculated dose distribution were carried out using gamma criteria of 3.5%/3.5 mm (% dose difference and mm distance to agreement). The gamma comparison performed with the ‘Verisoft’ software is shown in figure 2 for the C shaped test plan.

Figure 1. a) Optical readout of calibration irradiation on the gel phantom.
b) Treatment plan generated for calibration

Figure 2. Gamma comparison performed with ‘Verisoft’ software.

The passing rate for the C shaped plan was above 90% for most points above 50% dose whereas several points below the 50% dose failed the passing criteria. The second test case with the butterfly shaped PTV had only a lower pass percentage of 85%.

4. Conclusion
FX gel with in-house optical cone beam CT readout has been successfully used for 3D dose comparison between the gel matrix and the TPS dose distribution. Though, the pass percentage with gamma criteria of 3.5%/3.5mm was much lower, careful calibration and proper selection of the region for dose comparison could further improve the results.
5. References

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