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Implementation of an efficient workflow process for gel dosimetry using 3D Slicer

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Abstract. One challenge in gel dosimetry is the manipulation and analysis of complex data sets from different systems. In this paper, we describe a simple and fast gel dosimetry analysis tool for radiation therapy dose deliveries. Using the open source medical imaging software *3D Slicer*, an extension was designed and implemented for the purpose of importing treatment planning system dose, CT imaging from simulation and at treatment, and optical CT gel dosimeter data. The extension also allows for calibration of gel dosimeter data, registration, and comparison of 3D dose distributions. The development of an open source gel dosimetry processing environment may help adoption of gels in the clinic.

1. Introduction

Recent developments in radiation therapy treatment modalities (intensity modulated radiation therapy, volumetric modulated radiation therapy, stereotactic body radiation therapy, etc.) have increased the complexity of radiation therapy treatments, producing advanced patient dose deliveries. Due to this complexity, verification of dose delivery and quality assurance of new treatment techniques to validate that the dose delivery to the patient is accurate and precise is crucial. While many clinical dosimeters measure point dose or two-dimensional dose distributions, these new treatment modalities benefit from full, three-dimensional verification of dose delivery.

Gel dosimeters have been shown to be promising tools for measuring and verifying radiation dose deliveries [1-4]. Typically, gel dosimeters are read out using modalities such as magnetic resonance imaging, x-ray computed tomography (CT), or optical CT. Optical CT is becoming more frequently used as it is a simple and convenient method of acquiring dose distribution information. One major challenge with gel dosimetry is the extensive post-irradiation data processing time involved in registering and calibrating the gel dosimeter, and making the subsequent comparisons between the measured gel dosimeter dose and the planned dose distribution to confirm accurate dose delivery. A gel dosimetry workflow formerly performed using Matlab (Mathworks, Natick, MA), running the Computational Environment for Radiotherapy Research (CERR, www.cerr.info) was implemented in 3D Slicer (www.slicer.org) using a custom workflow extension called a *slicelet*. 3D Slicer is a powerful, open source, and free computational tool for image analysis and visualization. It features advanced volume rendering, interactive segmentation, rigid and non-rigid registration, slice viewers, and also includes a library of downloadable extensions which are designed and customized by 3D



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Slicer users for specific clinical tasks. A set of features in 3D Slicer tailored to radiation therapy specific tasks called *SlicerRT* [5] has recently been created, which enables loading of DICOM-RT data, manipulation of structure set contours, computation and display of dose-volume histograms, quantitative comparison of dose volumes and contours, and dose visualization.

2. Materials and Methods

Building on the SlicerRT extension, a slicelet for gel dosimetry analysis was developed following the general workflow shown in figure 1. In this paper, the main features of the slicelet are presented using the example of a 7 field intensity modulated radiation therapy plan that was delivered to a 1L jar of Fricke xylitol gel, mounted in a Quasar pelvic phantom (Modus Medical Devices Inc., London, Ontario). Gels were imaged using a Vista Optical CT Scanner (Modus Medical Devices Inc.).

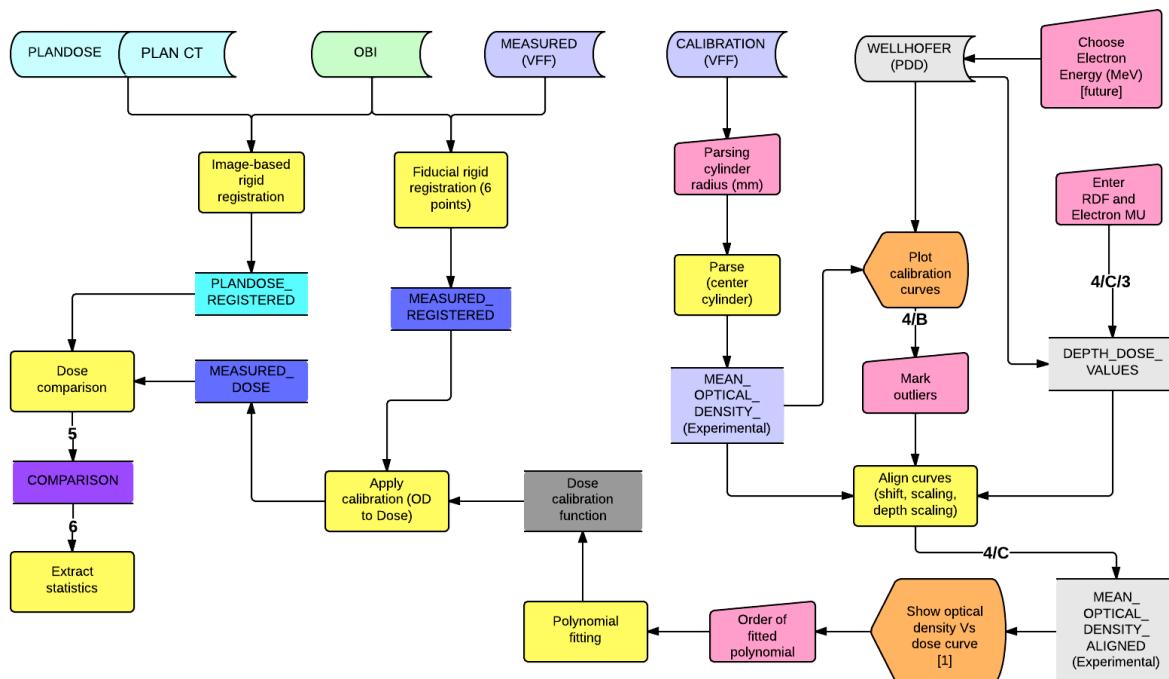


Figure 1. The workflow of the gel dosimetry analysis slicelet showing the incorporation of planning data (upper left), optical CT data (VFF file format), gel calibration (right), and dose comparison (bottom left).

2.1. Import DICOM data and registration to on-board imaging

As shown in the top row of figure 1, the radiation dose, planning CT images (and structure contours), and on-board imager (OBI) CT DICOM files were imported into 3D Slicer (figure 2). Using rigid body intensity based registration (pre-existing in 3D Slicer), the planning CT images, structure contours, and radiation dose were registered to the OBI CT imaging (figure 3).

2.2. Optical CT registration

Prior to dose delivery, 6 pen markings were made on the jar to act as fiducial markers: 2 sets of 3 coplanar points. Small ball bearings were fixed to the jar on top of each pen marking, and a cone beam CT was taken using the OBI to localize the ball bearings. After dose delivery, the ball bearing fiducials were removed, optical CT imaging was performed, and the reconstructed optical CT file ('MEASURED (VFF)' in figure 1) was imported to 3D Slicer using a file importer plugin developed specifically for this purpose. The 6 fiducial points were selected on the optical CT images (figure 4) using the gel analysis slicelet and registered to the OBI fiducial points using a rigid registration.

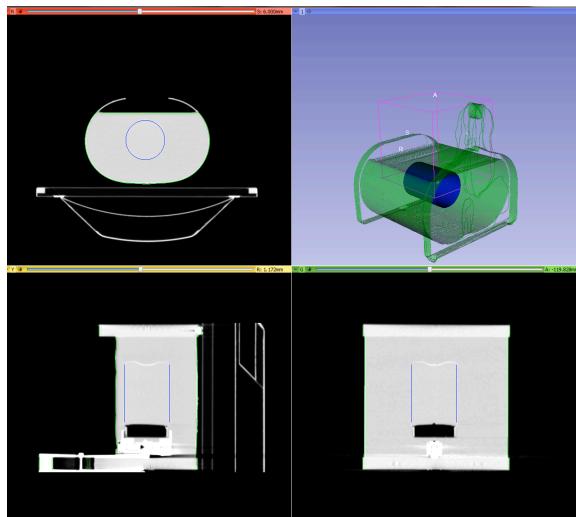


Figure 2. Imported planning CT images, showing gel jar and body structures.

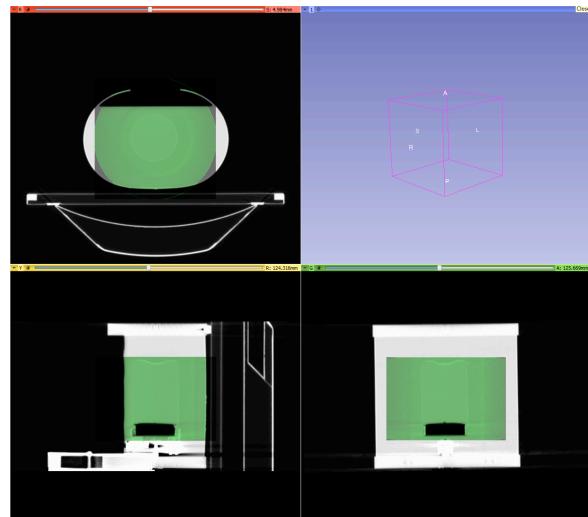


Figure 3. Registered planning CT imaging (grey) and OBI CT imaging (green).

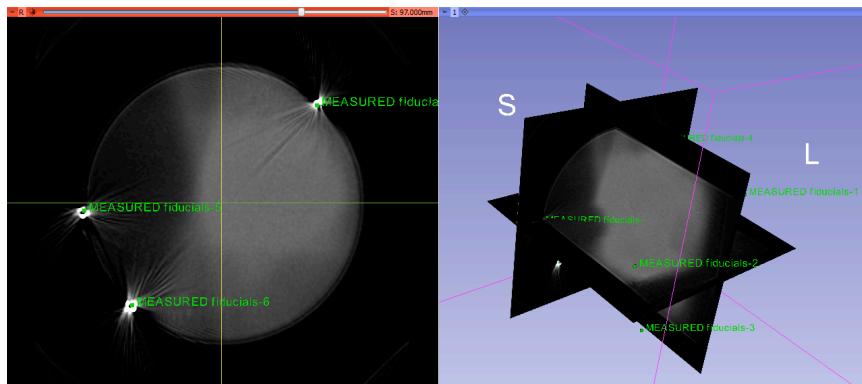


Figure 4. Fiducial point selection using the optical CT data.

2.3. Optical CT calibration

A 12 MeV, $6 \times 6 \text{ cm}^2$ field, 230 MU electron beam was delivered to the surface of a second jar with Fricke xylenol gel from the same batch (SSD=100cm) to calibrate the gel response to dose, and an optical CT of the jar was acquired ('CALIBRATION (VFF)' in figure 1). The optical density values through the central axis of the jar (averaging across a user defined radius (i.e. 10 mm)) were taken, and commissioned ion chamber depth dose data ('WELLHOFER (PDD)' in figure 1) for a 12MeV electron beam was imported to the slicelet. The two curves (optical density vs. depth, and percent depth dose vs. depth) were aligned using a minimization routine in the slicelet. Using the aligned curves, optical density was plotted against dose. The user selected the order of polynomial fit function to be used for the calibration. In this case, the data was fit using a linear function (figure 5). This calibration function was then applied to the first gel jar ('MEASURED_REGISTERED' in figure 1) to convert optical density measurements into dose values (figure 6).

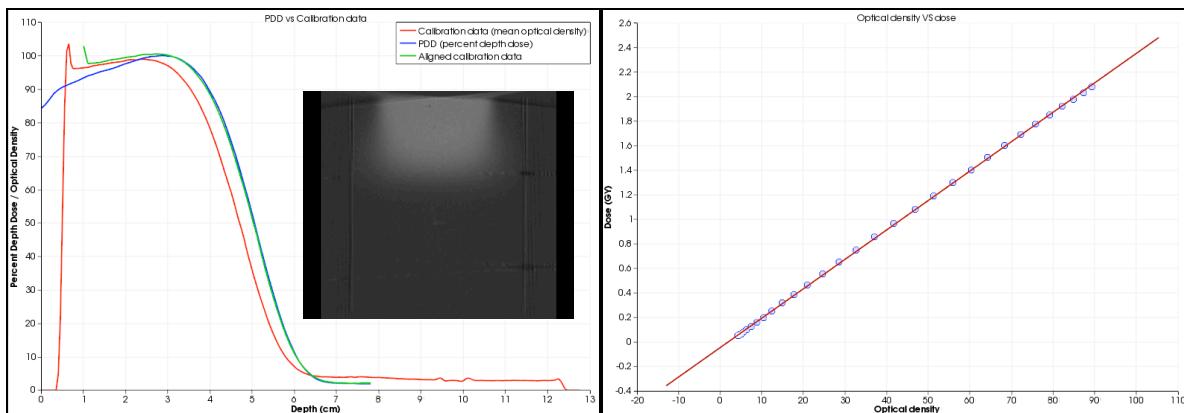


Figure 5. A sagittal slice view of the calibration gel dosimeter optical CT data (inset), the percent depth dose curve alignment (left), and the calibration line data and fit (right).

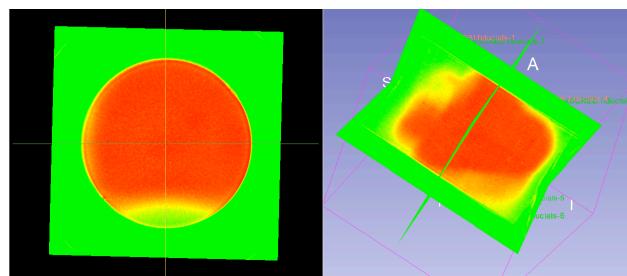


Figure 6. Calibrated optical CT gel data.

3. Results and Conclusions

After calibrating the optical CT gel data, the final step in the gel dosimetry analysis slicelet is to compare the measured optical CT dose data with the planned dose delivery distribution. The slicelet features a gamma comparison tool, and allows the user flexibility in setting the distance to agreement and dose difference, as well as the option to only calculate the gamma values inside the gel jar structure. Examples of the gamma comparison portion of the slicelet can be found in this conference's proceedings [6]. In this work, Olding *et al* used the gel dosimetry analysis slicelet to validate stereotactic ablative body radiation delivery using volumetric modulated arc therapy.

Overall, the gel dosimetry analysis slicelet has been proven to be a simple and efficient way to quickly analyze gel dosimetry data. Previous gel analysis using Matlab and CERR was lengthy and processing time would take several hours. Using this slicelet, processing time is reduced to about 10 minutes, facilitating easier clinical adoption of gel dosimetry. Further improvements are underway to expand the capabilities and scope of the slicelet to allow for more flexibility and slight variations in the typical workflow.

4. References

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