

Development of 3D Slicer Based Film Dosimetry Analysis

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Abstract. Radiochromic film dosimetry has been widely adopted in the clinic as it is a convenient option for dose measurement and verification. Film dosimetry analysis is typically performed using expensive commercial software, or custom made scripts in Matlab. However, common clinical film analysis software is not transparent regarding what corrections/optimizations are running behind the scenes. In this work, an extension to the open-source medical imaging platform *3D Slicer* was developed and implemented in our centre for film dosimetry analysis. This extension streamlines importing treatment planning system dose and film imaging data, film calibration, registration, and comparison of 2D dose distributions, enabling greater accessibility to film analysis and higher reliability.

1. Introduction

Dose delivery validation in modern clinical radiation therapy (RT) is difficult, as treatment techniques have become increasingly complex. This has led to the need for high-resolution detectors to accurately measure radiation dose distributions. One convenient clinical dosimetry option is radiochromic film as it is near tissue equivalent, energy and dose rate independent, and is an integrating dosimeter. Film dosimeter use is widely published and has been used for quality assurance, small field dose measurements, and as part of the commissioning of new machines and treatment techniques. At the last IC3DDose conference, we presented new, open-source 3D gel dosimetry analysis software, which streamlined gel dosimeter analysis from hours to 5-10 minutes [1]. Since then, we have recognized that an open-source film dosimetry analysis software would also be a useful clinical tool for film dosimetry. This work presents the initial development and implementation of such software.

2. Materials and Methods

In our clinic, film dosimetry analysis was previously performed using commercial software which was expensive and which performed corrections and optimizations (data smoothing, non-uniformity corrections), sometimes without the user's knowledge. To overcome these challenges and software license costs, a streamlined user interface for a 2D film dosimetry workflow has been implemented in 3D Slicer, as an extension called a *slicelet*. 3D Slicer is a medical software platform with advanced graphics rendering, segmentation, and registration capabilities. 3D Slicer is a good fit for film dosimetry analysis, as it is a free, open-source and customizable computational tool used for image analysis and visualization. The film dosimetry analysis slicelet draws on tools developed for radio-

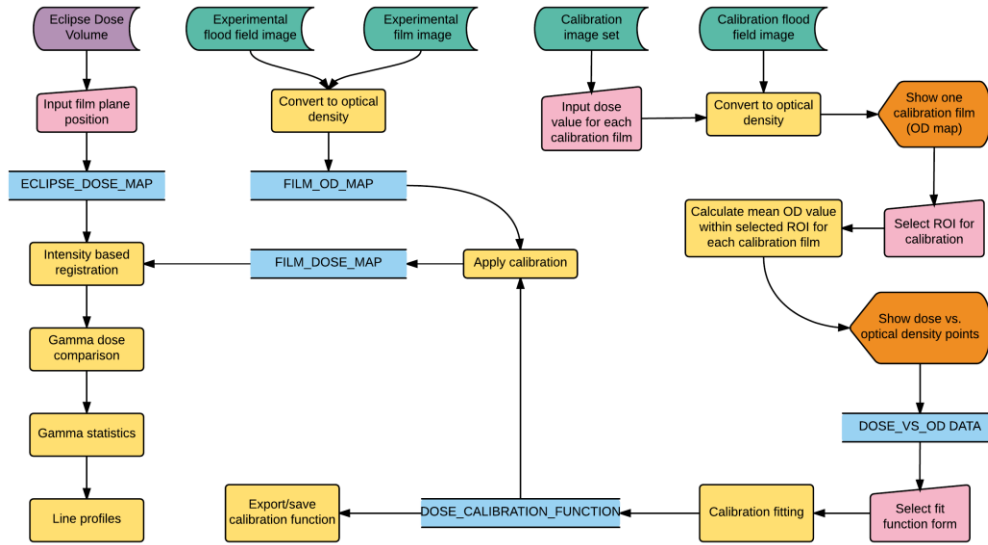


Figure 1. The workflow of the Film Dosimetry Analysis slicelet showing the planning data (upper left), film imaging data (top), film calibration (right), and dose comparison (bottom left).

therapy called *SlicerRT* [2] (www.slicerrt.org), which contains a multitude of RT-specific features, such as loading of DICOM-RT data, computation and display of dose-volume histograms, manipulation of structures, dose comparisons, and dose distribution visualization.

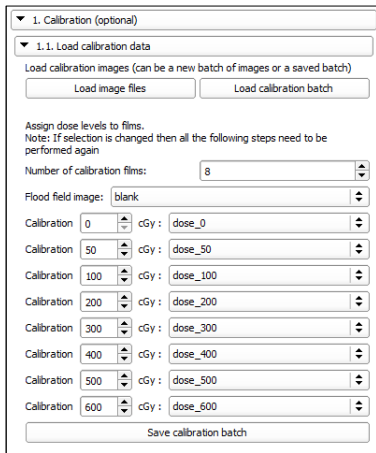
In this work, we present the initial development, implementation, and testing of the Film Dosimetry Analysis slicelet, which follows the general workflow shown in figure 1. The testing was performed using Gafchromic EBT3 film (International Specialty Products (ISP) Corporation, Wayne, NJ) coupled with our custom built, in-house CCD lightbox film dosimetry imaging system, using single red channel dosimetry methods. Using the CCD lightbox film imaging system with a diffuse red light field, flood field images are acquired without any film placed on the light field surface to provide a reference against which to normalize the image of the irradiated film. The irradiated film images are acquired with the film of interest placed flat on the light field surface. Using these images, the optical density for each pixel of each film is calculated. A sample film dosimetry case taken from our clinic's commissioning work on a new fractionated stereotactic radiation therapy (FSRT) brain metastases treatment is presented to demonstrate the functionality of the slicelet.

2.1. Calibration

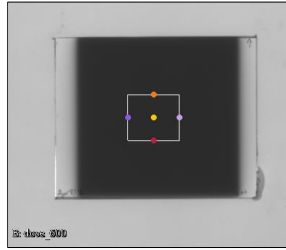
In order to calibrate the film for dosimetry, a relationship between the optical density and the absorbed dose during irradiation is determined. This is performed by irradiating several films to known doses under well-defined conditions (e.g. $10 \times 10 \text{ cm}^2$ fields) in order to establish the film response model. These calibration films are imaged and a flood field image is acquired. The images of these films and the flood field are then imported into the slicelet and assigned their appropriate dose value, or assigned as the flood field image. For example, in this case calibration doses of 0, 50, 100, 200, 300, 400, and 500 cGy were loaded along with a flood field image (figure 2a). Next, a region of interest is chosen, which defines a uniform region of the calibration films (figure 2b) and an average optical density value is calculated within that region for each calibration film. These corresponding optical density and dose values are then plotted and fit using the following function [4] (figure 2c):

$$\text{Dose} = a + b \cdot OD + c \cdot OD^n,$$

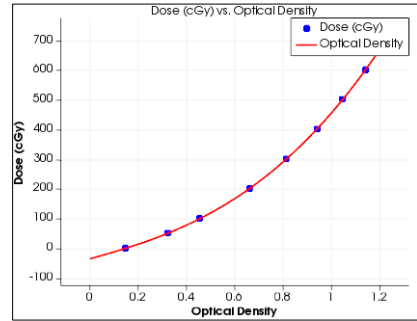
where fit parameters a , b , c are constants determined by a least squares fitting function, and n is limited to the range of [1.00, 4.00]. When this calibration routine is complete, the fit parameters automatically populate the fields of the slicelet. Fit parameters can be saved to a text file for future use.



(a)



(b)

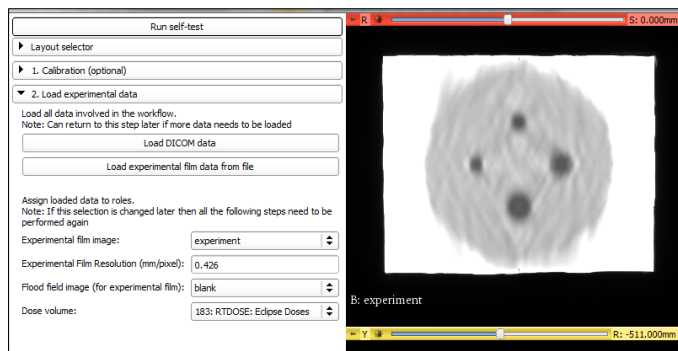


(c)

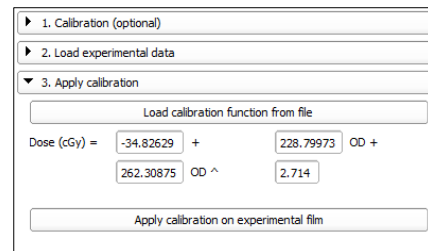
Figure 2. a) A screenshot of the graphical user interface of the calibration tab in the 3D Slicer Film Dosimetry Analysis slicelet. b) A region of interest drawn about the central, uniform region of a 600 cGy irradiated film (10 x 10 cm² field size). c) Calibration curve generated using the slicelet and fitted using the n -power polynomial function.

2.2. Load experimental data and apply calibration

The experimental film for this test case is a VMAT FSRT brain metastases treatment with 4 Gy prescribed to each of the four metastases (varying in size from 8-20 mm in diameter), and a 2 Gy whole brain dose. In this step of the slicelet, the DICOM dose and structures, and the experimental film image is also imported. The imported experimental film image, flood field image, and the DICOM dose volume are then assigned their respective roles, and the film resolution is input, in units of mm/pixel (figure 3a). The calibration function is then applied to the experimental film to convert to dose (figure 3b).



(a)



(b)

Figure 3. a) Screenshot showing the ‘load experimental data’ options and an image of the experimental film. b) Screenshot of the ‘apply calibration’ step, where fit parameters appear after performing the calibration step (step 1). These values can also be manually input.

2.3. Film registration

In order to register the film measurement to the calculated dose plane, the coronal plane at isocenter is extracted from the DICOM dose volume. The experimental film is also resized from pixels to distance in millimetres. The experimental film is then registered using a rigid registration built-in to the BRAINSfit registration module in 3D Slicer (figure 4a).

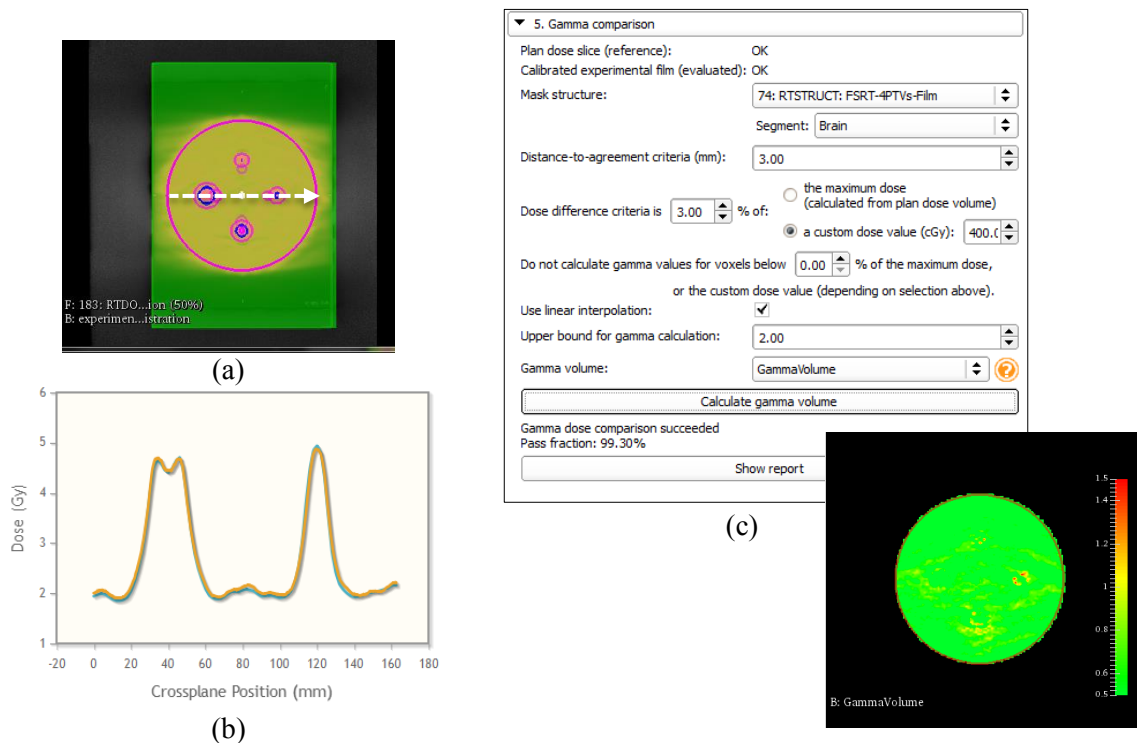


Figure 4. a) Film (green) after completing a rigid registration to the planned dose (grey) and structure set. b) Dose profiles about the registered experimental film (orange) and Eclipse (blue) dose distributions, as indicated by the line drawn in figure 4a. c) Screenshot of the user interface for the gamma comparison tool, and plane of gamma value calculated within the brain structure.

3. Results and Conclusions

After calibrating and registering the film measurement, the final step in the film dosimetry analysis slicelet is to compare that measurement to the planned dose distribution by using a 2D gamma dose comparison (figure 4c). The gamma dose comparison tool allows the user to set the distance to agreement and dose difference, as well as the option to only calculate the gamma values above a minimum dose threshold, or within a particular structure. In this example, excellent agreement between the measured and planned dose distributions was shown, resulting in a 3%/3mm gamma pass rate within the brain structure of 99.3%. Dose profiles also show excellent agreement (figure 4b).

Overall, the film dosimetry analysis slicelet streamlines complex film analysis; another example of its use can be found in a clinical example reported in this conference's proceedings [3]. This open-source analysis tool helps make film dosimetry more accessible and transparent. It also enables convenient film dosimetry, free from the constraint of commercial analysis or read out systems. Future work will look at implementing multichannel dosimetry methods in the slicelet. This poster, along with a workshop during the meeting, will show how 3D Slicer can facilitate efficient 2D and 3D dosimetry.

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