Slicelet implementation for gel dosimetry analysis

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PURPOSE: The complexity of the open-source SlicerRT toolkit [1] provides a large degree of flexibility to the user, but can make some routine workflows inconvenient to perform. New features and interfaces are needed to streamline these processes into simple, user-friendly workflows. Gel dosimetry analysis is a tool used in commissioning new radiation techniques and to validate the accuracy of radiation treatment by enabling visual comparison of the planned dose to the delivered dose, where correspondence between the two dose distributions is achieved using embedded landmarks. Gel dosimetry is based on imaging chemical systems spatially fixed in gelatin, which exhibit a detectable change upon irradiation. This chemical change is related to the amount of radiation received and can be probed by several imaging techniques, allowing 3D dose information to be obtained. The purpose of this project was to design and implement a custom workflow and user interface, called a *slicelet*, based on the 3D Slicer platform and SlicerRT. This slicelet would enable simultaneous visualization and comparison of the computed treatment planning dose to the delivered gel dose, and would simplify a currently complex analysis process.

METHODS: 3D Slicer (www.slicer.org) is an open-source software platform for medical image visualization and analysis. SlicerRT (www.SlicerRT.org) is an open-source radiation therapy research toolkit developed for 3D Slicer [1]. SlicerRT provides specific measurement tools such as contour comparison, dose volume histograms and dose comparison. A slicelet is a simplified custom workflow and user interface that uses the features and functionalities of the 3D Slicer platform and 3D Slicer-based toolkits, including SlicerRT. We designed and implemented our slicelet in Python, utilizing many functions already existing in 3D Slicer and SlicerRT. Our slicelet currently consists of the following steps: data loading, registration using BRAINSFit general registration, registration using manually segmented fiducials, dose calibration, performing statistical tests, and extracting the statistics from the workflow. The optical CT data containing the measured dose is in a special format, called VFF. A file reader has been developed for this format that integrates into the data IO mechanism of 3D Slicer. The dose registration accuracy was evaluated using two different methods in order to show that the slicelet enabled visual comparison of the dose distributions. The first approach used visual confirmation that the registered and transformed fiducials corresponded correctly. The second method used target reconstruction error, computed after running 10 tests on sample IMRT planned dose data.

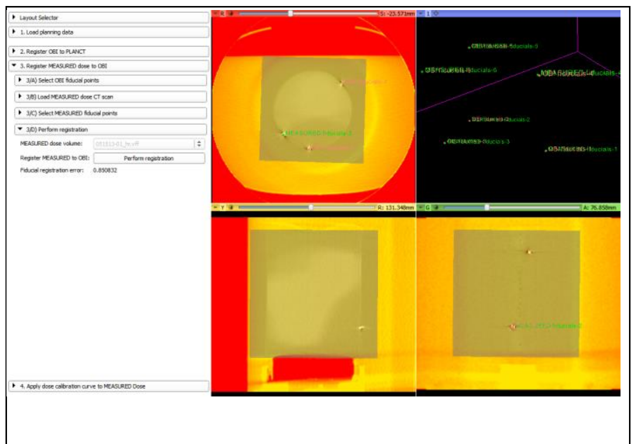

Figure 1. Fiducial markers from the planned dose distribution and from the delivered dose distribution shown following registration and transformation.

RESULTS AND DISCUSSION: The workflow has been implemented (Figure 1), and provides all of the required capabilities for image registration and transformation so that the planning distribution of the computed dose and that of the delivered dose can be compared. The image registration has been qualitatively validated using visual confirmation that the corresponding fiducials are correctly registered. This can be seen by observing that the fiducials from the two distributions, and their corresponding image volumes, are overlaid following registration and transformation. Image registration was also quantitatively validated by computing the target reconstruction error (TRE) of the registration. To do this we computed the registration of the delivered dose to the planned dose using five fiducial landmarks from each volume, and a sixth fiducial from each was randomly chosen each time to compute the TRE. The TRE was 1.7 ± 0.3 mm for 10 tests indicating that the registration was accurate, as this error is less than the typical treatment planning resolution of 2.5 mm, so the error will have no significant impact on the result of the gel dosimetry analysis. To reduce the current lengthy analysis time, this slicelet was designed to help streamline the gel dosimetry analysis process. This slicelet provides a significant step in helping to bring gel dosimetry into common clinical use. Future developments will include improving the user interface and slicelet interactions to support more functions, such as contour comparison. We are also trying to select the most appropriate metrics to use in our slicelet, such as dose volume histograms and gamma evaluations. In conclusion, the initial steps of our slicelet have been implemented, and have been shown to produce the correct results. This has been demonstrated through visual confirmation that the delivered dose fiducials have been correctly registered and transformed, as well as by the low TRE that resulted after 10 tests. We believe that the simplicity of the slicelet will appeal to users who are inexperienced with 3D Slicer or SlicerRT, and will facilitate collaboration between the image guided therapy, radiation oncology, and medical physics communities.

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[1] C. Pinter, A. Lasso, A. Wang, D. Jaffray, and G. Fichtinger, "SlicerRT: Radiation therapy research toolkit for 3D Slicer", Med. Phys. 39(10), 6332/7 (2012).