Investigation of 3D Gamma Analysis for Clinical SRS Treatments

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Introduction

Stereotactic Radiosurgery (SRS) utilizes precise patient positioning and a higher single radiation dose fraction delivered to a focused area. Due to the small treatment fields, it is challenging to perform patient specific quality assurance (PSQA) using conventional methods, e.g. two-dimensional (2D) detector arrays due to their low spatial resolutions. Recently, EBT3 films with submillimeter resolution have been commonly used to resolve this problem.

However, owing to the highly irregular and steep dose gradients of SRS plans, evaluation of 2D dose distribution along the isocenter may not be sufficient to properly determine the acceptance of treatment QA.

In this study, both the capability and importance of using PRESAGE 3D dosimeter (Heuris Inc.) for PSQA was investigated.

Materials and Methods

First, the feasibility of using PRESAGE for small field dosimetry was investigated. Beam field sizes of 6, 8, 10, 12 mm defined by MLC and jaws were delivered to a single dosimeter by TrueBeam (Varian Inc.) for beam profiles and output factors measurements. The results were compared with those measured with EBT3 films and the microDiamond detector.

Furthermore, to verify the accuracy of dose distribution measurement, a clinical small field treatment for spinal metastasis (2 cm^2 field size) was delivered to the 3D dosimeter. 2D dose distribution acquired along isocenter was compared to the film measurement.

After evaluation of the feasibility of 3-D PRESAGE for small field dosimetry, the importance of using a 3-D dosimeter for PSQA was assessed. 3D dose distribution of an highly modulated SRS plan (4 cm^2 field size) was first measured by the PRESAGE dosimeter. Then, 2D gamma tests of the dose distribution at different slices were conducted. Difference of the passing rates between each slice indicates the importance of acquiring 3D information for PSQA.

In this study, a single-beam optical scanner with 0.07 mm resolution of each projection and 1200 projections was used to scan the 3D dosimeter. Images were reconstructed using filtered-back projection with optimal protocol to achieve good image quality (resolution, signal-to-noise ratio).

Results and Discussion

Small Field Dosimetry of PRESAGE

1. Beam Profiles Comparison

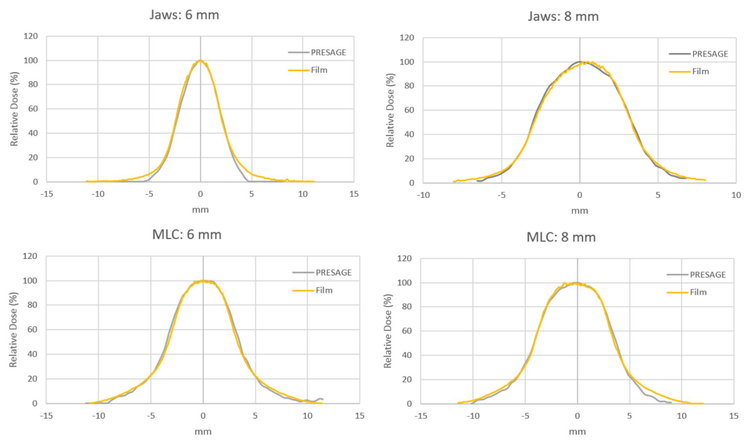

Figure 1: Beam profiles comparison of PRESAGE and Film using 6, 8 mm FS defined by MLC and jaws.

- The dose at each point was normalized to the maximum dose of beam profiles. Therefore, the resolution of the dosimeter used becomes important for small field measurement, which influences the maximum dose measured.
- The measured penumbras and FWHMs by PRESAGE agree with EBT3 film within 2%.

2. Output Factors Measurement

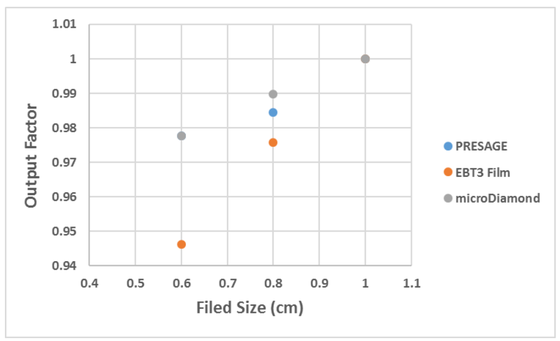

Figure 2: Output factor measurement of PRESAGE, EBT3 film and microdiamond.

- Output factors in this study were defined as the maximum dose of each field sizes divided by what of 1 cm FS.
- Output factors measured by PRESAGE corresponds to what measured by microDiamond with error smaller than 1%. On the other hand, EBT3 underestimates the output by 3% when field size goes down to 6 mm.

2D Dose Distribution Measurement

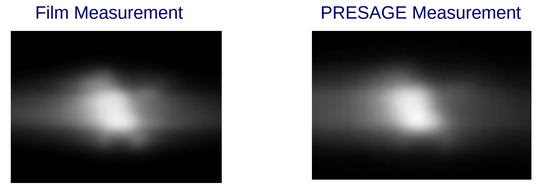

Figure 3: Scanned and reconstructed images from films and PRESAGEs

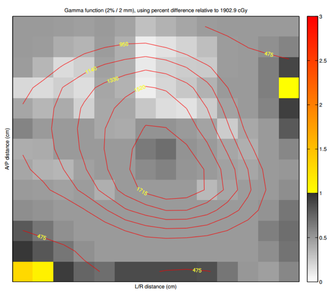

Figure 4: Gamma difference map of the two images using criteria of 2%/2 mm.

- 98.4% of pixels pass gamma for 2% relative dose / 2 mm criteria (10% threshold).
- PRESAGE has sufficient resolution capability to measure dose distribution of irregular, high-gradient treatment fields.

2D Gamma Test at Different Depths

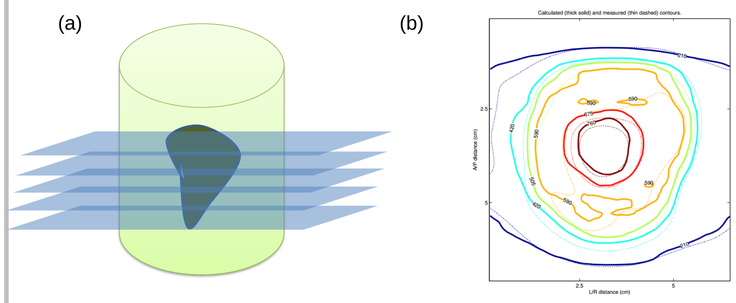

Figure 5: (a) 2D gamma test at different slices were analyzed. (b) Dose distribution comparison of the failed slice.

- 2D gamma test at different depths were conducted with 3%/3mm criteria. (Fig. 5 (a)) Passing rate of the plane at isocenter is 90.4% similar to the result of film, 90.2%.
- The lowest passing rate is 78.4% at 1.3 cm below the target. Fig. 5 (b) shows the difference of isodose lines at the depth. The treatment was thus replanned to achieve higher passing rate.

Conclusions

This study demonstrates that with appropriate scanning and reconstruction techniques, PRESAGE 3D dosimeter can become an accurate tool to evaluate clinical small field treatments. In addition, 2D gamma test at the isocenter may not be sufficient to make acceptance judgement of the SRS plans. Future work includes more measurements of output factors and other clinical plans to provide statistical evaluation.