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Dose Verification of Stereotactic Radiosurgery Treatment for Trigeminal Neuralgia with Presage 3D Dosimetry System

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Abstract. Achieving adequate verification and quality-assurance (QA) for radiosurgery treatment of trigeminal neuralgia (TGN) is particularly challenging because of the combination of very small fields, very high doses, and complex irradiation geometries (multiple gantry and couch combinations). TGN treatments have extreme requirements for dosimetry tools and QA techniques, to ensure adequate verification. In this work we evaluate the potential of Presage/Optical-CT dosimetry system as a tool for the verification of TGN distributions in high-resolution and in 3D. A TGN treatment was planned and delivered to a Presage 3D dosimeter positioned inside the Radiological-Physics-Center (RPC) head and neck IMRT credentialing phantom. A 6-arc treatment plan was created using the iPlan system, and a maximum dose of 80Gy was delivered with a Varian Trilogy machine. The delivered dose to Presage was determined by optical-CT scanning using the \textbf{Duke Large field-of-view Optical-CT Scanner} (DLOS) in 3D, with isotropic resolution of 0.7mm\textsuperscript{3}. DLOS scanning and reconstruction took about 20minutes. 3D dose comparisons were made with the planning system. Good agreement was observed between the planned and measured 3D dose distributions, and this work provides strong support for the viability of Presage/Optical-CT as a highly useful new approach for verification of this complex technique.

1. Introduction

The radiation dose for stereotactic radiosurgery (SRS) treatment of trigeminal neuralgia is usually several folds higher than typical SRS doses for brain tumors [1]. The aperture of the radiation beam for trigeminal neuralgia SRS treatment is usually very small, i.e., 4–5 mm in diameter. The dose measurement and characterization of such treatment can be challenging since conventional dose measurement devices, such as ion chambers, may exhibit volume averaging artifacts, and also it is difficult to accurately place the dosimeter at the absolute maximum dose point. Presage dosimetry system can measure the three-dimensional (3D) dose distribution with very fine spatial resolution, and therefore can potentially be an ideal tool to measure the dose for trigeminal neuralgia SRS. This study investigated the feasibility of using the Presage dosimetry system to measure the 3D dose distribution of a trigeminal SRS treatment with a Radiological Physics Center (RPC) head neck (HN) phantom. The measured dose was compared with the planned dose.

2. Materials and Methods

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2.1. Phantom setup
A cylindrical Presage dosimeter (~12 cm diameter by 15 cm length) was inserted into the RPC HN phantom at the position of typical trigeminal neuralgia SRS treatment. A Brainlab head ring was mounted to the phantom, as shown in figure 1.

![Figure 1: HN phantom mounted in a head ring.](image)

2.2. SRS Planning
A CT scan of the phantom mounted on the head ring was performed with a Brainlab localizer. The slice thickness of the CT images was 0.625 mm. The CT images were sent to a Brainlab iPlan system for treatment planning.

The CT images were first localized with iPlan and an isocenter was placed at a typical trigeminal neuralgia SRS treatment position. 7 arcs with a total of 700 degrees were used in the treatment plan. 6 MV photons with a circular collimator of 4 mm in diameter were used for treatment. 80 Gy was prescribed to the maximum dose point. The dose calculation voxel size was set to 1 mm x 1 mm x 1 mm. The Presage dosimeter was then taken out of the phantom for pre-scanning using the Duke Large Optical-CT Scanner (DLOS) described in an accompanying abstract (Thomas et al. [2], see also Sakhalkar et al. [3]).

2.3. Treatment Delivery
A Novalis TX linear accelerator (LINAC) was used for treatment. The dosimeter was reinserted into the phantom before the treatment. Accurate and reproducible insert alignment within the phantom was achieved by marks scratched on the dosimeter, and aligned with matching marks on the RPC phantom. The phantom was then mounted to the LINAC couch as shown in Fig. 1, and localized to the isocenter position with a localization box. A set of cone beam CT (CBCT) images was then obtained and matched to the planning CT. The phantom was then automatically moved to the treatment position based on CBCT matched result. 7 arcs were then delivered at 1000 MU/minute.

2.4. Dose Measurement
The Presage dosimeter was taken out from the phantom after the treatment was completed and immediately scanned with the DLOS optical CT scanner.

The calibration curve was obtained separately with 5 calibration points determined from small cuvettes of Presage from the same batch (1x1x5 cm) irradiated to varying known doses. The linearity of dose response of Presage dosimeter was also tested up to 80 Gy. The calibration curve was applied to convert Optical-CT pixel values (corresponding to optical attenuation coefficients) to radiation doses. Planning CT doses were exported from iPlan SRS planning system and fused to the Presage scans for comparison.

3. Results
3.1. SRS Plan Isodoses
The isodoses of the SRS plan was displayed in figure 2. The monitor units (MU) numbers for the arcs were 2844, 2851, 2518, 2450, 2558, 2479, and 2306.

![iPlan SRS plan isodoses](image)

Figure 2: iPlan SRS plan isodoses

3.2. Presage Linearity Test and Calibration
The Presage test showed a linear response within the whole dose range up to the maximum dose we tested of 80Gy. The calibration curve is shown in Figure 3.

![Calibration curve](image)

Figure 3: Calibration curve

3.3. Presage dose measurement and comparison
The calculated and measured 3D dose distributions (iPlan and Presage respectively) were imported into CERR [4], registered, and compared using overlays, and profiles (Figure 4 a-c). The dose profiles of the measured and corresponding planning doses are plotted on the right side of the pictures. The relative dose-differences are displayed below the profiles.

The dose volume histograms (DVH) were also plotted for both the measured and planned dose, as shown in Fig. 4 d). The maximum dose as measured with Presage was 85.0 cGy. It matched reasonably well with the prescribed maximum dose of 80.0 Gy.
4. Discussion and Conclusions

The maximum dose as measured by the Presage dosimeter was slightly higher than the planned maximum dose. We speculate that the higher dose reported by Presage could be closer to the actual delivered dose because of the fine spatial resolution of the Presage measurement, i.e., a reduced volume averaging effect when compared with the commissioning data used in iPlan. The profiles of the measured dose were slightly wider than the planned dose by about 1 mm. This difference may also be real, caused by the imperfect isocenter of the treatment machine. As the gantry and couch rotate between different arcs, slight variations in the isocenter position may lead to a broadening of the delivered distribution when compared to the ideal calculation in iPlan which has no allowance for gantry sag and couch drift. This feasibility study showed that Presage dosimetry system works well for the dose measurement of the trigeminal neuralgia SRS treatment.

References


