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Abstract
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Evaluation of a Novel Patient-Specific Quality Assurance Phantom for Robotic Single-Isocenter, Multiple Target (SIMT) Stereotactic Radiosurgery

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Abstract

Objective: To explore the utility of a novel film-based patient-specific quality assurance (PSQA) device for robotic single-isocenter, multiple target (SIMT) stereotactic radiosurgery (SRS).

Methods: In a Euclidean space, a plane is uniquely determined by three non-collinear points. Applying this to PSQA for SRS, a measurement film plane can be made to intersect with any three targets during a course of irradiation. The NavPhan (Navaxis, NY), a spherical phantom (20 cm diameter) containing an internal film cartridge and imbedded fiducials, was designed to achieve this purpose with sub-millimeter accuracy. The system includes a specialized positioning stand that allows-for free rotation about the sphere's center and a software which can accurately compute the setup geometry, extract a 2D dose plane from a 3D DICOM dataset and generate virtual CT scans in the measurement geometry for image guided setup.

The Precision treatment planning system (TPS) was used to create 15 patient-specific test plans. These plans were mapped to the virtual CT scan of the phantom and the dose was recomputed. DICOM points of interest were selected in sets of three to represent treatment targets within the dose distribution. These points were entered into the phantom software system to compute the measurement setup necessary to intersect a film with each set of points. The 3D dose distribution was exported to the phantom software and the software extracted each predicted film plane. All plans were delivered on the CyberKnife system using fiducial tracking to ensure sub-millimeter setup accuracy. The irradiated films were scanned and processed with care, including generating a calibration curve from the film strips from the same QA film batch.

Results: A total of 15 CyberKnife SIMT patient plans with three different treatment modalities were retrospectively delivered on the phantom. The averaged plan delivery time was 28.6 ± 4.3 mins, 22.4 ± 5.0 mins and 19.2 ± 5.8 mins for cone, Iris and MLC, respectively. When registering the irradiated film and TPS dose plane, both automatic and marker-based registration methods were applied. For the latter, the customized marks on the films and on the exported dose were used for alignment. Gamma analysis was performed using 3%/1 mm, 2%/1 mm and 1%/1 mm with 10% threshold. For automatic registration method, the mean passing rates were 99.3 ± 1.1%, 97.6 ± 2.8% and 89.0 ± 6.7% respectively. For the marker-based registration approach, the mean passing rates were 98.5 ± 1.4%, 95.8 ± 2.9% and 83.9 ± 5.8% respectively. The mean distance from the isocenter to the metastasis was 3.9 ± 1.5 cm (the maximal distance of 6.7 cm).

Conclusion: A novel spherical phantom was evaluated for robotic SIMT SRS and resulted in excellent passing rates. The NavPhan system can measure full-composite dose of arbitrarily placed targets and offers high resolution results for PSQA. This makes it a valuable tool for robotic radiosurgery and SIMT verification alike.