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Quality Assurance System for End-to-End Verification of Dosimetric and Spatial Accuracy of Small-field Radiation Delivery Suitable for Functional SRS

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Abstract

Objectives: Design phantoms and procedures with 0.1 mm or better accuracy for assessing spatial and dosimetric performance of accelerator-based radiation delivery with small fields. Use the system to demonstrate that a standard treatment planning system (TPS) provides accurate doses for gantry arcs with MLC-defined fields as small as 1.6x5mm2. Measure couch walkout and assess its effect on dose distributions for treatments at multiple couch angles. Design a treatment plan usable for functional SRS.

Methods: The 2D institution-built phantom accommodates GafChromic film in the coronal plane. It has a 5 cm radius circle engraved at the film plane that is clearly visible during kV image-based setup. Matching with a similar computer-generated contour provides phantom positioning better than 0.1 mm. Couch walkout is measured along the three principal coordinates using a dial gauge. The 3D end-to-end verification phantom has a 3x3x3 mm3 air-filled cavity with film passing through its center. It provides for marking film to accurately assess the 3D position of the intended target center with the delivered dose cloud. The target is defined during treatment planning from a simulation CT as the center of the cavity. Films are evaluated using home-developed software and ImageJ.

Results: The dose of single-arc irradiations delivered to the 2D phantom agreed with the TPS within 2.4 ±2.0%, averaged over 10 measurements of each of the field sizes 1.6X5, 2.0x5, 2.4x5, 5x5, 10x10, 15x15, 20x20, 25x25, and 30x30 mm2. Dose profiles agreed within 0.2 mm for all field sizes. The target was missed by an average 2D vector error of 0.18±0.1 mm, with a maximum of 0.33 mm. A pointer originally set up at Conebeam CT (CBCT) isocenter shifted its position by up to 0.6 mm in the horizontal plane as the couch was rotated. Vertical walkout was negligible. Planning for a 9-arc arrangement to be delivered to the 2D phantom with 2.4x5 mm arcs at 6 different couch angles, suitable for functional SRS, indicated that couch walkout would shift the dose cloud by 0.16 mm. Film measurements showed average dose and spatial errors of 0.3±2.0% and 0.20 ±0.08 mm, respectively. Planned 9-arc end-to-end irradiation of the 3D phantom, which included a simulation CT, followed by contouring the air cavity agreed with measurements dosimetrically within 1.7±1.7% and spatially within 0.31±0.10 mm. The largest geographic miss was 0.42 mm. Computed and measured dose distributions of the 9-arc arrangement matched and agreed well with the dose cloud of a GammaKnife with 4 mm collimator. The accurate results confirm not only the validity of our quality assurance (QA) method but also the suitability of accelerators for SRS. The TPS can be used to plan arc

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arrangements as needed for individual patients.

Conclusions: The unique features of our QA procedures, together with the 2D and 3D phantoms provide the means for accurately assessing accelerator performance. Using these we confirmed that accelerator-based SRS can be planned and reliably delivered to cranial targets with 0.5 mm spatial and 3% dosimetric accuracy. We consider end-to-end tests essential since estimation of over-all accuracy based on individual errors may over- or underestimate actual results.