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SRS Quality Assurance Using Real-Time Optical Imaging

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Abstract

Objectives: In Stereotactic body radiation therapy (SBRT) and stereotactic radiosurgery (SRS) the highly conformal dose given over 3-4 fractions requires use of small beamlets with low penumbra and a steep dose fall-off rate. It is imperative that routine QA (Percentage Dose Depth and Cross Beam Profiles), and patient specific SRS/SBRT plans QA be performed accurately. Quality assurance is currently performed using radiographic films, Ionization Chambers, Electronic Portal Imaging Device (EPID), and diode array systems. Most of these lead to a workflow which is time consuming and are limited because of spatial resolution or energy resolution inaccuracy for the most complex beamlets. In this study, we propose a remote, real-time optical imaging technique that uses a pulsed intensified CMOS camera to capture optical photons generated due to Cherenkov radiation in water tank doped with quinine sulfate.

Methods: A 140mm diameter x 305mm deep cylindrical water phantom doped with 1g/L quinine sulfate was imaged using an intensified time-gated (CMOS) camera (C-Dose, DoseOptics LLC., Lebanon, NH). The water phantom was CT-scanned and a range of static beams and dynamic plans were simulated through this in the Eclipse treatment planning system (TPS). These plans were then delivered to the phantom, from a TrueBeam linac. Static square beams of 5mm, 10mm and 50mm delivered to the phantom for initial testing. Dynamic plans included a 5mm full 360-degree arc, a head and neck VMAT and a multi-target SRS plan with couch kicks. The resulting image stacks from each experiment were analyzed both dynamically and as an average of all frames. For the static beams, the percentage dose depth (PDD) and cross beam profiles (CBP) were obtained from the averaged frame. Gamma analysis was performed on all plans relative to the TPS image data.

Results: We were able to achieve a frame rate of 10-18 frames per second (fps) for the dynamic plans. With the camera 2m away from the isocenter, a spatial resolution 0.26mm was achieved. Comparison of each experimental PDD against each TPS PDD showed that for the smallest beam sizes, 5mm, a 96.5% gamma pass rate was achieved with a 3%/3mm criteria. For the 10mm and 50mm square beams, the pass rate was 97.5% and 100% respectively. For CBP's, the 3%/3mm passing rate was 100% in the beam width region but discrepancies were seen in the penumbra region. The composite image of the 5mm 360 arc plan and the dynamic head and neck VMAT showed a 100% and 98.8% pass rate for 3%/3mm criteria, respectively. The multi-target SRS Plan with couch kicks resulted in a 93.4% pass rate for the 5%/5mm criteria.

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Conclusions: Remote optical Cherenkov imaging has been demonstrated as a suitable alternative QA technique for small beamlets that are relevant in SRS and SBRT plans. Small beams near 5mm are detectable and agree well with the TPS data. QA's performed using EPID and diode arrays usually overwrite couch kicks and do not give accurate description of dose deposition, whereas in this study, the multi-target SRS plan with the couch kicks was imaged with the camera fixed to the patient frame of reference, thereby enabling us to take in to account the mechanical uncertainty of the isocenter. With 10-18 frames per second, this technique allowed us to capture data per single control point for the dynamic plans.

Disclosure of Conflicts of Interest: Brian W. Pogue is the Co-Founder, President of Dose Optics (Lebanon, NH).