A Cost-effective, Machine-blind, End-to-end Isodose-based Winston-Lutz Test Phantom for Image-guided Stereotactic Radiosurgery of Off-centered Targets

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Objectives: Image-guided Stereotactic Radio-Surgery (SRS) has been rapidly adopted as an indispensable modality for treating multiple metastatic brain lesions. To facilitate the internationally multi-institutional study on such treatments using different treatment modalities across different countries, a simple and cost-effective phantom for quality assurance is necessary. In this study, a film-based 2D slab phantom for SRS of multiple off-centered targets was designed and validated for the first time to realize the isodose-based Winston-Lutz (WL) test.

Methods: The conventional WL test was performed for the Truebeam STx linac to evaluate the isocenter deviation. An in-house developed 2D slab phantom with three metallic cross markers (aluminum wire of 0.1 mm diameters) was used for the isodose-based WL test. The Gafchromic EBT3 film was cut and placed in the phantom for measurement. The central marker was placed in the middle of the phantom while the other two were placed in the upper left by 2.7 cm (“close target”) and lower right by 4.7 cm (“far target”). The phantom was CT scanned with 1mm slice thickness. The plan isocenter was placed on the cross of the central marker. Three spherical targets of 1.5 cm diameters were contoured with their centers overlapped with the markers. MLC leaves were set to fit all the targets in the beam’s eye view. The dose WL plan (3 Gy/fx, 100% prescription to the mean volume of the central target) included the combination of gantry angles of 0, 30, and 330 degrees; collimator angles of 0, 60, and 90 degrees; and couch angles of 0, 45, 90, and 270 degrees. The CBCT was used for phantom setup. The film was punched by a needle (where the central marker was) to represent the linac isocenter. Dose was calculated in Eclipse (v15.6) treatment planning system (TPS). The 50% of the isodose line was used to determine the dosimetric center of the target. The deviation between the machine isocenter and the dosimetric center of the central target was firstly evaluated. Then, the film measurement was registered to the TPS calculated planar dose with a gradient dose stripe using the intensity-based rigid image registration. The difference in three target dose centers between the TPS calculations and film measurements were evaluated. The film measurements were repeated three times on three different days.

Results: The deviations (mean ± standard deviation) between the linac isocenter and the dosimetric center of the central target were 0.3±0.2 mm and 0.4±0.2 mm in left-right (LR) and superior-inferior (SI) directions, respectively. The center deviations found in the isodose-WL test for the central target were 0.3±0.1 mm (LR) and 0.2±0.2 mm (SI); center deviations of the "close target" were 0.4±0.2 mm (LR) and 0.3±0.1 mm (SI); and center deviations of the "far target" were 0.5±0.3 mm (LR) and 0.6±0.2 mm (SI).

Conclusion(s): A simple and cost-effective (less than $18) phantom was developed and demonstrated for performing accurate and consistent measurement for isodose-based WL test as mandated by cooperative studies of treating a high number of off-center targets with SRS. The isodose-based WL test can accurately quantify the increase in the treatment deviation as the target gets further away from the isocenter. Further studies are underway to improve the robustness in the imaging analysis and registration processes for non-linac SRS modalities.