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Demonstrating the Potential of the ZAP-X MV Imager for Linac Quality Assurance

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Abstract

Objectives: The ZAP-X Gyroscopic Radiosurgery System implemented an improved MV Imager 2.0 with version DP-1009. The MV Imager is a scintillator-camera system that generates a 1000x1000 pixel TIF file with a resolution of 0.037 mm/pixel at isocenter. The MV Imager has underutilized potential for performance of Linac QA tests. In this work, I characterize the MV Imager 2.0, investigating linearity, reproducibility, and noise. I then demonstrate the capabilities of the Imager with a suite of Linac QA tests. I also share the tests' analysis using in-house developed Matlab code.

Methods: Linearity of the MV Imager response was assessed for irradiations ranging from 5 to 500MU. Reproducibility was assessed for 10 sequential irradiations, followed by delayed irradiations ranging from 1 to 60 minutes.
A photon beam profile constancy test was performed for all 8 aperture sizes. Having irradiated these 8 fields without any mechanical movements other than the collimator wheel, the centering of each beam relative to each other was analyzed.
To check X-ray off axis factor constancy vs. gantry angle as described in AAPM TG-142, the end piece of the ZAP-X couch is removed so that unobstructed beams from many axial and oblique gantry angles can be acquired and compared using a gamma analysis. This set of images can also be analyzed for beam centroid.
Finally, I evaluated the positioning reproducibility of the collimator wheel. For this test the 4mm aperture was imaged; the collimator wheel was "Homed;" and then 4mm aperture was imaged; repeated multiple times. The centering of this set of beams was analyzed.
The majority of these tests were executed on the ZAP-X utilizing the Wizard: Script Execution service tool to automatically deliver programmed beam sequences.

Results: The ZAP-X MV Imager linearity and stability establishes it as a reliable tool for Linac QA. Minimal noise filtering is necessary for image processing. Beam profile constancy is demonstrated to within the ±2% daily constancy metric from AAPM MPPG 8.b. The 8 aperture centers coincide to within a maximum deviation of 0.2mm (projected to isocenter). Beam profile constancy vs. gantry angle analysis shows >90% passing points for all 36 beams in Node Path 3 using a 1%/0.5mm gamma criteria and CAX absolute output vs. gantry angle is within 1% of the Home gantry angle. Gantry angle beam centroids agree to within 0.3mm. The collimator wheel reproducibility results are within 0.01mm.

Conclusion(s): The test of beam centering for each aperture is an essential SRS Linac QA test, particularly for the ZAP-X which uses a wheel mechanism to change the aperture selection. Typical Winston-Lutz type tests are all performed using larger apertures, and the beam alignment accuracy can only be extended to the smaller field sizes by doing an analysis such as this centering test. While this relative centering check may be performed using water tank profile scans, the MV Imager is much more convenient.
This work is the first to describe the X-ray off axis factor constancy vs. gantry angle test for a ZAP-X.
The results presented here demonstrate acceptable beam performance of the ZAP-X SRS delivery platform.
The MV Imager's ease of use enables more extensive testing and increased testing frequency. By demonstrating the potential of the MV Imager, I hope to see further development by Zap Surgical, third-party QA software vendors, and other ZAP-X users to improve upon the analysis tools available to analyze the MV Imager TIF files.