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Gyroscopic Radiosurgery: Performance and Stability Over First Year of Clinical Use

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Abstract
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Abstract

Objectives:

The ZAP-X is a novel, self-shielded system for cranial radiosurgery with a 3 MV linear accelerator mounted on a gyroscopic gantry. In this study, we evaluate accuracy, stability and dosimetric properties over the first year of clinical use.

Methods:

The ZAP-X system produces circular fields with diameters of 4 to 25 mm in a reference distance of 45 cm. Beam profiles, depth dose curves and output factors were measured in a water phantom (PTW MP3-XS) with a microdiamond detector (PTW 60019) and an SRS diode (PTW 60018) and confirmed quarterly. System accuracy and precision were determined via 17 End-To-End Tests, 8 starshot tests for both gantry axes and 85 steelball tests (Winston-Lutz equivalent test to evaluate kV- and MV- isocenter congruency). OSL dosimeters were placed onto walls in the treatment room to evaluate the self-shielding properties of the system over the whole year. Characteristics of clinical treatments were summarized.

Results:

Beam penumbra widths range from 1.58 mm (4 mm collimator) to 1.94 mm (25 mm collimator) in the reference depth of 7 mm. Output factors of the smallest fields are 0.716 (4 mm collimator) and 0.808 (5 mm collimator). End-to-end tests show a total system accuracy of 0.38 ± 0.12 mm (max. 0.62 mm). From starshot tests, the isocenter diameter is quantified to 0.19 ± 0.11 mm (max. 0.36 mm) on the axial, and 0.14 ± 0.08 mm (max. 0.31 mm) on the oblique gantry axis. Steelball tests exhibit minimal variation over 1 year, with a radial positioning accuracy via kV imaging of 0.31 ± 0.11 mm (max. 0.71 mm), and a radial divergence of the treatment beam of 0.21 ± 0.05 mm (max. 0.31 mm).
Ambient dose measurements inside the treatment room show an additional exposure of 0.18 ± 0.08 mSv/year averaged over all five OSL dosimeters (max. 0.32 mSv/year).
Planning target volumes range from 0.09 to 20.06 cm^3 with a median volume of 1.32 cm^3. Benign lesions and metastases are treated with doses between 13 and 22 Gy to a median isodose of 52.5% (40 – 82.4%). Plans use a mean beam-on time of 7 ± 2 min, with 100 ± 34 beams per lesion and 8 ± 4 isocenters per lesion. The mean gradient index was 3.1 ± 0.5.

Conclusion(s):

The ZAP-X exhibits high accuracy and sharp beam penumbras suitable for radiosurgical applications. During the first year of operation, the geometry of the gyroscopically mounted components remained stable and the self-shielding was found to be adequate.