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Quality Assurance for Monitoring Beam Orientation in Gyroscopic Stereotactic Radiosurgery Systems

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Abstract
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Abstract

Objectives:

Photon-based stereotactic radiosurgery (SRS) can be administered utilizing either isocentric or non-isocentric methodologies. Within the domain of isocentric delivery, gyroscopic configuration has been adopted for the development of a recent commercially available SRS system. This SRS system, underpinned by gyroscopic principles, facilitates the attainment of precise isocentric delivery, affording the advantage of easy and frequent verification of beam iso-centricity. However, a noticeable gap in QA pertaining to beam entry angles is evident. In response, we introduce an innovative procedure involving the deployment of a cylindrical array of diodes. This approach offers a systematic and integral means to monitor and ensure the consistency of beam entry angles as an essential component of a comprehensive QA program.

Methods:

An array of 1386 diodes, each with a volume of 0.019 mm^3, is arranged in cylindrical configuration with a diameter of 21 cm, resulting in a density of 221 diodes per 10x10 cm^2. The device (commercially available) has been used for patient-specific plan QA in conventional IMRT and VMAT, as well as in the QA procedures for beam characteristics.

The proposed procedure for employing this device in QA for beam entry angles in the context of gyroscopic SRS systems involves the following steps:
1. Development of a QA plan with a single isocenter and a specific beam path positioned at the center of the cylindrical diode array.
2. Exportation of the resulting dose matrix to the QA software database.
3. Delivery of the QA plan to the device under image-guided alignment.
4. Utilization of the initial measurement as the baseline reference.
5. Subsequent delivery of QA plans at designated time intervals (e.g., daily, weekly, or monthly).
6. Comparison of the measured results with the baseline reference, and interpretation of the analyzing results.

It is noteworthy that the density (resolution) of the diode array may not be sufficiently high to enable a meaningful comparison between the calculated and measured diode readings to infer the quality of target dose distributions. However, this limitation does not preclude the sensitivity of the system in detecting variations in beam entry angles. This heightened sensitivity arises from the steep dose fall-off inherent to the dose profile of individual SRS beams, leading to significant variations in diode readings with even small shifts in the beam entry angle.

Results:

A beam path consisting of 44 beams was used for QA plans with various sizes of collimators, ranging from 4mm to 25mm. The detecting sensitivity of beam angel was quantified as the percentage of failure per degree deviation in comparative analysis. Our findings revealed a notable trend: as the collimator size increased, the detecting sensitivity decreased. Specifically, it was observed that the collimator size of 10 mm yielded optimal results for our testing, aligning with the fact that the diode spacing within the device also corresponds to 10 mm. For the 10 mm collimation setting, our study demonstrated detecting sensitivities of 30.0%, 31.2%, and 44.1% per degree angular deviation, with the setting of 3%, 2% and 1% dose tolerance and 10% threshold, respectively.

Conclusion(s):

In the context of isocentric SRS delivery, the angular deviation of beam entries may not substantially impact the dose distribution around the treatment target volume. However, it can potentially impose uncertain dosimetric consequences for peripheral critical structures. This justifies the need of implementing a dependable QA procedure to monitor the consistency of beam entry angles, at an appropriate frequency. The procedure we have introduced has proven its capability to provide sufficient detecting sensitivity to fulfill this critical task, ensuring that the integrity of radiation treatment is maintained while safeguarding surrounding critical structures from unintended radiation exposure.