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Random Sporadic Patient-Specific Stereotactic Uncertainties for Frame-based Brain Radiosurgery

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Abstract
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Abstract

Objective: Rigid frame-based stereotacxy has served as the gold standard for stereotactic radiosurgery. With the introduction of on-online stereotactic cone-beam CT (sCBCT) imaging, patient-specific uncertainties associated with rigid frame-based stereotactic definition can be directly measured prior to the treatment delivery. In this study, we investigated patient-specific uncertainties associated with conventional rigid frame-based stereotaxy for brain radiosurgery.

Methods: sCBCT imaging was introduced for the Gamma Knife radiosurgery via the latest Icon (GKI) unit at our institution since 2017. Specific to stereotactic definition, we have performed pre-treatment phantom measurements as well as pre-treatment stereotactic serial CT (sCT) and sCBCT measurements in addition to the MR-based stereotactic definition measurements for selected brain radiosurgery cases (N=16). The phantom measurements were performed via a plastic cylindrical grid phantom. Pre-treatment measurements were performed via comparing MR imaging studies that were mapped with stereotactic coordinates via the following method: (1) stereotactic localizer box attached to the frame for MR imaging studies (2) stereotactic localizer box attached to the frame for sCT scans (3) online sCBCT acquired prior to the beam-on delivery. Stereotactic coordinates of 6-12 anatomical and device landmarks were identified via auto-segmentation. These coordinates were compared among these stereotactic definition methods.

Results: Discrepancy among three stereotactic definitions ranged from 0.2 to 2.5 mm (0.81 ±0.67 mm). Of note, the large discrepancy was predominantly observed in the peripheral skull region and along the axial z-axis direction. However, the occurrences of shifts exceeding 1.0 mm were determined to be random and sporadic for the studied cases with respect to variable MR scanning sequences, target sizes and locations, as well as patient head-tilt angles.

Conclusion: Sporadic uncertainties on the order of 1.5 mm were detected for conventional frame-based stereotactic definition. As a result, independent validation of stereotactic definition is strongly recommended to ensure delivery accuracy. Shortening duration of the metal frame attached to the patient's skull is currently being investigated to reduce these unexpected uncertainties.