Cureus

Patient-Specific QA for Multi-Target Single-Isocenter Intracranial SRS Plans with LINAC

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Abstract
Published 03/06/2024

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Categories: Medical Physics, Radiation Oncology
Keywords: linac

How to cite this abstract
Lee T, Spirydovich S (March 06, 2024) Patient-Specific QA for Multi-Target Single-Isocenter Intracranial SRS Plans with LINAC. Cureus 16(3): a1146

Abstract

Objectives:

As radiotherapy treatment techniques have evolved, so does the treatment planning techniques for multi-target intracranial SRS (stereotactic radiosurgery) cases. With accurate beam configuration and reproducible beam delivery at high precision, it has become enabled to create a plan with a single isocenter that treats multi-targets, which can be referred to as Multi-Target Single-Isocenter (MTSI). However, in performing patient specific QA (PSQA) with a high-resolution diode array QA device, it is, in general, impossible to accommodate all targets in one QA of a treatment plan. Therefore, we have performed PSQA relocating each target or each neighboring target group (T-NTG) relative to the beam isocenter on the QA device so that each target dose coverage is verified at high resolution.

Methods:

At our institution, the SRS treatment plans are calculated with 6MV–FFF (Flattening-Filter-Free) beams. The plans are composed of four VMAT arcs, with one full arc and three half arcs with couch-kicks. The script has been written and used to calculate the coordinates of the center of each T-NTG relative to the beam isocenter. In creating the QA verification plans, we maintained the beam parameters including the gantry, collimator, and couch rotations from the original patient treatment plans. While in the initial PSQA plan, the beam isocenter is located at the user origin, in our approach we redefined the beam isocenter for each so that the T-NTG in such a way that it is positioned at the center of the QA device. In other words, the center of the QA device is spatially moved to the center of each T-NTG for PSQA. The QA plans were created for each T-NTG. Each plan was exported in a dicom format for PSQA. During PSQA, CBCT (Cone-Beam Computed Tomography) images were acquired for the QA device alignment. Note that there is a possibility of collision for anteriorly or laterally located T-NTG relative to the user origin. For our QA device, we identified the maximum shift distances below which there is no collision, and we kept the shift distances below that when relocating the T-NTG. We used full-arc head CBCT with high-resolution, with which the alignment accuracy is <= 0.5 mm. When each plan is imported into the QA device software, we defined a dicom user origin for each target plan so that the intended T-NTG is centered on the QA device. Once each QA plan is measured, we performed gamma index analysis (GIA) using the criteria DTA (Distance-To-Agreement) of 1.0-1.5mm and absolute dose PDD (Percent Dose Difference) of 2.0%, and Threshold of 10%. We first started the GIA with 1.0mm / 2.0%, and if the passing rate (PR) is <= 95.0%, repeated the GIA with 1.5mm / 2.0% considering the user setup error of up to 0.5mm for QA device alignment with CBCT. We have performed a paired t-test for PR values of randomly selected 25 patients treated in 2021-2023, who had 2 – 6 targets which resulted in 75 QA verification plans among which 18 plans were with two-target NTGs.

Results:

Performing gamma index analysis for each QA plan with those criteria, the passing rate (PR), that is defined as percentage of measured points that satisfy Gamma Index < 1, is > 95.5% with the average 98.9%. PR > 99.0% was 45 plans and > 97.0% was 63 plans, which are 60% and 84% of studied plans, respectively.
We also performed a single-tail paired t-test with ideal PR value of 100%, which resulted in statistical significance, while that performed with the PR value of 99% resulted in statistical insignificance, which indicates that performing PSQA for individual target may not meet 100% PR in general but do 99% most cases.

Conclusion(s):

In MTSI cases that use 6MV-FFF beams, some targets are located on lateral dose-fall off region due to the

nature of FFF beams, and so the coverage of each target must be verified for the acceptability. Our clinical study on the relocation of individual T-NTG shows that the presented methods can be generally acceptable as the PR is statistically insignificant against PR value of 99%, which indicates that the presented PSQA method can serve as a reliable QA tool in clinic.