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Pretreatment Dose Verification for Intensity-Modulated Stereotactic Radiosurgery for Arteriovenous Malformations Using Monte Carlo Simulations and Measurements

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Abstract
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Abstract

Objectives:

This study aims to evaluate the accuracy of dose calculations for arteriovenous malformation (AVM) treatment plans generated using the Eclipse™ TPS by comparing them with Monte Carlo (MC) simulations and point dose measurements. Additionally, the study seeks to validate an indigenously fabricated PMMA head phantom for pre-treatment verification.

Methods:

The treatment plans of 30 AVM patients were selected for this study retrospectively based on the prescribed dose. In Eclipse Treatment Planning System (TPS), three sets of VMAT plans were generated, one using AAA and two using Acuros® XB Dm and Acuros® XB Dw, respectively. Pre-treatment verification plans for these 30 patients were generated on an indigenously fabricated PMMA head phantom using Eclipse™ v15.6.05 planning system to perform the point dose measurements. The measurements were carried out using a True BeamTM (Varian Medical Systems®) linear accelerator. To verify the accuracy of Eclipse™ planning system the measured dose was compared with the Monte Carlo simulation and TPS calculated dose. Simulations were performed using PRIMO MC Code. Initially, validation of phase space for the 6MV photon beam for True Beam™ was done by comparing the simulated percentage depth dose (PDD) and transverse profiles against the measured curves, which were acquired during the commissioning. In addition, validation of the treatment planning system was also performed on an indigenously fabricated PMMA head phantom using MC simulation in conjunction with point dose measurements.

Results:

Gamma analysis of measured and simulated PDD curves and profiles shows a minimum pass rate of 99% and 97.42%, utilizing 2 mm DTA and 2% percentage dose variations. The comparison of treatment plans obtained from PRIMO and TPS reveals that Acuros® XB Dw underestimates the TPS calculated dose by 1.83%. The mean % deviation between the simulated and TPS calculated dose was much smaller for AAA and Acuros® XB Dm with -0.72% and -0.30%. The p-value between the simulated dose and the dose calculated by Acuros® XB Dm was found to be 0.007. The % deviation between the measured and TPS calculated doses was studied, the maximum mean % dose variation was observed for Acuros® XB Dw (2.89%), and the minimum mean dose variation was observed for Acuros® XB Dm with -0.46%. The statistical analysis of the detector's mean dosage for both measured and MC was insignificant with a p-value of 0.427.

Conclusion(s):

The study demonstrates that Acuros® XB Dm and AAA models exhibit superior dosimetric accuracy with minimal deviation from TPS-calculated doses, while Acuros® XB Dw shows a higher dose underestimation. Patient-specific dose estimations using Monte Carlo (MC) simulations and point dose measurements were evaluated, confirming strong agreement with measured data. The use of an indigenously fabricated head phantom provided a reliable platform for validating these dose estimations in clinical settings.