Monte Carlo modeling of the Novalis TX stereotactic radiosurgery mode

An electron beam with Gaussian distribution was used for the simulation of the photon source in BEAMnrc. To account for the new flattening filter in the Varian Novalis TX linear accelerator stereotactic (SRS) mode, the source parameters of beam energy, size and angular spread, were modified to achieve agreement with measurements in water. Having had difficulty characterizing the source parameters following our current procedure\textsuperscript{1}, a recent approach by Almberg et al.\textsuperscript{2} was used instead. Almberg determines the source’s energy by matching to ion chamber percent depth measurements (PDD) in water (5 x 5 cm\textsuperscript{2}), the source’s size (the FWHM of the Gaussian distribution) by matching to film penumbra measurements of a 5 x 5 cm\textsuperscript{2} field, and the angular spread by matching ion chamber profile measurements at 1.5 cm and 10 cm depths in water. Our application of this procedure succeeded in characterizing the source parameters so that they predict PDDs and beam profiles to within 2\% of measurements in water for jaw-defined fields.

The Varian 120-leaf high definition (HD120) multi-leaf collimator (MLC) was then modeled. The HD120 differs from previous MLCs in that it contains two sets of target/isocenter leaves (excluding the outboard leaves) with smaller leaves projecting 2.5 mm width at isocenter. A previously coded DYNVMLC component module\textsuperscript{3}, with the ability to model one set of target/isocenter leaves, was reprogrammed to include the two sets present in the HD120. A “ray trace”, generated by logging the coordinates of a particle whenever it crossed a boundary into another medium, was performed to visualize the geometry of the modeled MLC. Fig. 1 shows this 2D ray trace of the HD120 component module, demonstrating the simulated geometry of the quarter and half target/isocenter leaf pairs with the tongues, grooves, leaf tips, driving screw holes, and support rails all clearly visible.

Following a similar procedure to those of Heath\textsuperscript{4} and Fix\textsuperscript{5}, our MLC model was validated with many film measurements, testing abutting and interleaf leakage, as well as the MLC’s ability to model complex distributions, either static or dynamic. EBT2 film was used for validation purposes, following the procedure originally set forth by Devic\textsuperscript{6} that uses calibration curves to convert the film’s optical density to dose, and extracts profiles from the film using MATLAB scripts. Specifically, the interleaf leakage profile was used to adjust two free parameters of the HDMLC model: the interleaf air gap and the leaf density. Both free parameters have dosimetric effects, but only the interleaf air gap has geometric effects. First, the air gap was adjusted to fit the film measurements geometrically, and then the density of the leaves was varied to fit the measurements dosimetrically. The interleaf air gap and leaf density was determined to be 0.0047 cm and 18.5 g/cc respectively. Compared to the results of Fix et al. and their modeling of the HD120, our density values agree but our interleaf air gaps differ slightly. Fig. 2 demonstrates that this disagreement may not be significant, as the irregular variations in the EBT2 film measurement are reproducible and most likely characteristic of the HD120 at the Montreal General Hospital. Minute differences in leaf size and position, accentuated by the small leaf dimensions of the quarter leaves (in the center), result in differences in interleaf leakage. The values in Fig. 2 are obtained by normalizing the blocked MLC field to open field measurements (15 x 15 cm\textsuperscript{2}). Fig. 3 demonstrates some of the more complex shapes that the HDMLC model can accommodate. The image shows an isodose line comparison with EBT2 film, using the commercial software: Film QA, where the thick lines are the Monte Carlo simulated dose.

Statement of Impact: To our knowledge, this is the first modeling of the SRS mode of the Novalis TX with the HD120 MLC for the BEAMnrc Monte Carlo code. This model will allow for the benchmarking of commercial treatment planning systems, including vendor supplied Monte Carlo codes.

![Figure 1](image1.png)

![Figure 2](image2.png)

![Figure 3](image3.png)

References: