Monte Carlo Validation of Simple Geometry in Homogeneous Medium for Pencil Beam Scanning

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PURPOSE

To validate Monte Carlo (MC) calculations with RayStation (v. 6.1.1.2) for proton pencil beam scanning for simple geometry in homogeneous medium with and without the presence of the range shifter.

METHOD

- Treatment plans were created using a synthetic water phantom.
- Rectangular right prisms of different positions and sizes were used as target volumes for calculation of various square field sizes for a set of energies and modulations.
- Treatment plans were optimized to create uniform doses in the target volume regions using Pencil Beam Algorithm (PBA) for open field and with the range shifter in three different snout positions.
- MC plans were copies of the PBA plans and calculated with 0.1% uncertainty.
- The spot map and MU/spot were the same in the open field plans and range shifter plans as well as between the two algorithms.

- Measurements of the SOBP curves were performed using the Zebra (a multilayer ionization chamber).
- Absolute dosimetry measurements were performed in the middle of the SOBP and in water with a PPC05 ion chamber.

RESULTS

- Open field measurements compared to PBA and MC calculations were less than 0.7%, as seen in Table 1.

CONCLUSIONS

- The larger discrepancies between calculated and measured data occurred for PBA when the range shifter was present.
- The discrepancy was gradually reduced between the measurement and PBA when the snout position was closer to the water tank (i.e. minimizing the air gap). MC calculations typically had smaller discrepancies from measurements regardless of snout position.

Table 1 Sampling of results for different range, modulation and setup for comparison between measurements and PBA versus MC

Range	Modulation	Range Shifter and Snout Position	Meas. (RBE, Gy)	PBA @ calced depth (Gy)	% Diff TPS PBA	MC @ calced depth (Gy)	% Diff TPS MC
15	3	No RS	2.19	2.20	0.43%	2.19	0.08%
		RS @42.2cm	2.25	2.36	4.76%	2.24	-0.16%
		RS @30.0cm	2.27	2.36	3.71%	2.27	-0.06%
		RS @ 17.6cm	2.32	2.36	1.93%	2.32	0.02%
20	3	No RS	2.20	2.20	-0.04%	2.20	-0.15%
		RS @42.2cm	2.28	2.36	3.05%	2.27	-0.45%
		RS @30.0cm	2.30	2.36	2.40%	2.29	-0.59%
		RS @ 17.6cm	2.33	2.35	1.25%	2.31	-0.52%
25	3	No RS	2.20	2.20	-0.01%	2.20	0.12%
		RS @42.2cm	2.29	2.35	2.72%	2.29	0.08%
		RS @30.0cm	2.30	2.35	2.18%	2.30	0.16%
		RS @ 17.6cm	2.32	2.35	1.37%	2.31	-0.18%
25	7	No RS	2.19	2.20	0.65%	2.20	0.71%
		RS @42.2cm	2.28	2.36	3.52%	2.29	0.73%
		RS @30.0cm	2.29	2.36	2.98%	2.30	0.53%
		RS @ 17.6cm	2.31	2.36	2.15%	2.33	0.65%
30	10	No RS	2.21	2.20	-0.62%	2.20	-0.21%
		RS @42.2cm	2.28	2.35	3.14%	2.30	0.77%
		RS @30.0cm	2.29	2.36	2.60%	2.31	0.71%
		RS @ 17.6cm	2.31	2.35	1.87%	2.32	0.59%

- We are using these results and others not presented here to help guide which cases we use Monte Carlo optimization and calculation with in our clinic.
- Monte Carlo provides the accurate modeling for beams with the range shifter when compared to measurements in a homogeneous medium.
- Due to the dosimetric discrepancies that are seen between PBA and measurements when the range shifter is present, we are recommending that these cases should planned with Monte Carlo.

CONTACT INFORMATION

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