Proton Beam Delivery to a Moving Lung Tumor and Monte Carlo Simulation with TOPAS

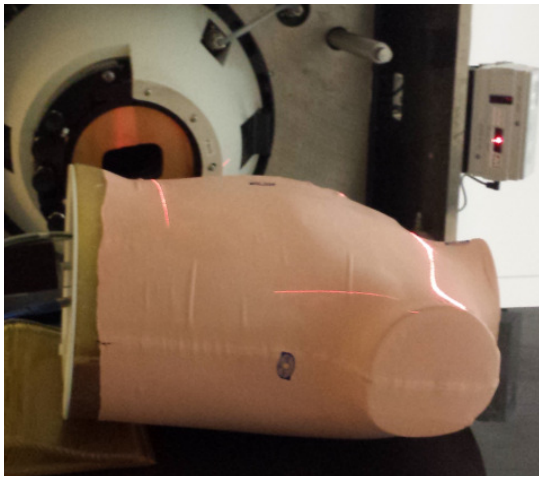
4/28/15

Innovation/Impact: We believe this study to be innovative since it compares two commonly used forms of proton beam modulation. It examines the relationship between proton beam modulation, and lung tumor motion using a phantom with tumor motion capability. It also compares these data to Monte Carlo simulations.

Methods and Materials: A radiology support devices (RSD) phantom was irradiated with therapeutic proton radiation beams (IBA©) from the Hampton University Proton Therapy Institute (HUPTI, see http://www.hamptonproton.org/). Figure 1 shows a picture of the RSD phantom prior to irradiation. Two different types of beam modulation were used: uniform scanning (US) and double scattered (DS)[i]. The simulated tumor within the phantom was approximately 3x3x3cm (27cc). Radiation dose was measured with an ion-chamber (CC-13). The Eclipse© treatment planning system (TPS) was used to create a radiation treatment plan delivering 100cGy of radiation dose to the static tumor with 100% coverage. Figure 2 shows the characteristics of the US scanning data. A similar table was produced for the DS data. Proton dose delivery to a moving tumor was also simulated via TOPAS[ii] Monte Carlo. The simulation software was run on an Apple MacBook© computer.

Results: Figure 3 shows both the US and DS dose data as a function of amplitude. As can be seen in this graph, the radiation dose delivered decreases as a function of amplitude, with the US having a lower coverage fraction than DS for higher amplitudes. Figure 4 shows a table of the ratio of US to DS dose. Figure 5 shows the simulated dose delivery to motion capable tumor in a TOPAS Monte Carlo simulation. The picture on the upper left is a lateral dose profile and the bottom left an axial dose profile.

Conclusion: The radiation dose deposited to a moving tumor was less than for a static tumor, as expected. At large (2.5cm) amplitudes, the DS proton beams gave a dose closer to the desired dose than the US beams, but equal within experimental uncertainty. Monte Carlo simulations with TOPAS can provide insight to tumor motion dose coverage.



Amp(cm)	Charge(pC)	Dose(Gy)	IC2(MU)	Time(sec)
0.0	-3.557	1.024690805	100.1	94.55
1.0	-3.375	0.972260745	100.1	95.05
1.5	-3.3965	0.978310367	100.1	92.30
2.0	-3.1865	0.917958181	100.2	92.15
2.5	-3.218	0.927032615	100.2	93.70

Figure 2: Uniform scanning data.

Figure 1: RSD Phantom prior to irradiation.

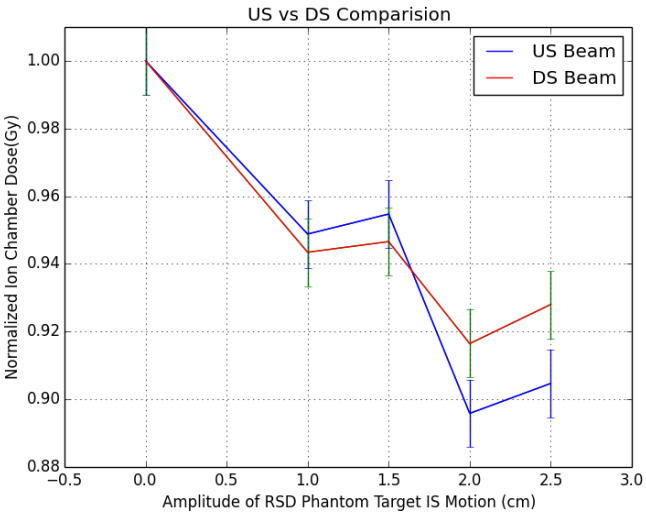


Figure 3: US and DS dose vs. tumor amplitude.

Amp(cm)	US/DS
0.0	1.01585035
1.0	1.021643711
1.5	1.024588927
2.0	0.99298847
2.5	0.990306201

Figure 4: US to DS dose ratio.

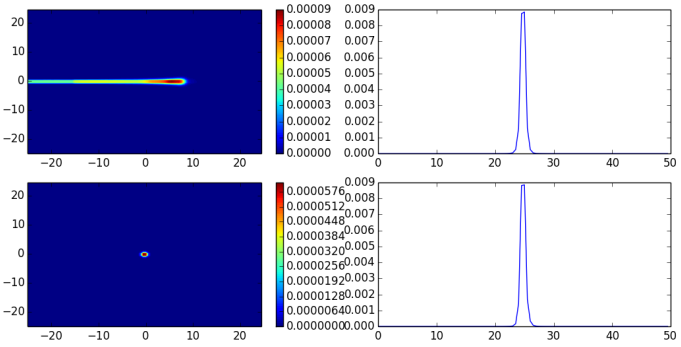


Figure 5: TOPAS Monte Carlo simulation.

[i] Paganetti, H. 'Proton Therapy Physics', CRC Press Taylor & Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742.

[ii] See http://www.topasmc.org/.