Evaluation of Heterogeneities in Proton Therapy

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INTRODUCTION

Accurate dose calculations in heterogeneous tissue compositions is extremely important for proton therapy. Tissue heterogeneity within the path of the protons can greatly affect the finite range and scatter of the proton beams. Compared to photons, heterogeneities in proton beams can lead to zero dose delivered to the target or overdosing critical structures. Ensuring that the treatment planning system dose algorithm is accurate, especially in regard to tissue heterogeneities is essential (1). Monte Carlo-based (MC) dose calculations have been found to be superior to analytical algorithms, especially in regions of high heterogeneity (2,3), but not all clinics with proton therapy have access to treatment planning systems (TSP) with MC capabilities.

AIM

To investigate the effect of heterogeneous materials in proton beams by evaluating and comparing dose distributions from measured Gafchromic film, calculations using a Proton Convolution Superposition dose algorithm, and calculations using Topas Monte Carlo simulation.

METHOD

A rectangular rod phantom generated with 3D printer with dimensions of 14cm x 10cm and thickness of 2cm, with 6 rods of various diameters, was scanned and imported into a TPS using Proton Convolution Superposition dose calculation and Topas Monte Carlo software for dose calculations. Figure 1 shows the setup and characteristics of the rod phantom, as well as solid water and film placement for the experiment. The phantom is robust since any configuration of different materials can be implemented in various positions and diameters. Ten cm of solid water was placed upstream and downstream the phantom, and films were placed downstream the phantom every 0.5cm depth to evaluate the dose distribution. Calculations of the dose distribution at the film locations based on the TPS and Monte Carlo were compared with measurements of the film based on two delivered treatment plans: 1) a single AP field resulting in uniform SOBP along the entire phantom and 2.5 cm downstream the phantom and 2) a single AP field resulting in a single energy Bragg Peak dose distribution with maximum dose 2.5 cm downstream the phantom. Ten variations of rod materials including solid water, air, brass, aluminum, copper and titanium were evaluated. The peaks and valleys of the dose distribution in planes through profiles were compared.

RESULTS

Preliminary results show inadequate estimation of the dose profiles based on TPS when heterogeneities of high Z material are introduced in the phantom. Figure 2 shows results for the dose distributions and profiles 1.5 cm downstream the rod phantom for the rod configuration with titanium as the heterogeneity. Figure 2a) shows the SOBP dose configuration and dose profiles comparing Topas MC, film measurement and TPS. Figure 2b) shows for the Bragg Peak dose configuration and dose profiles comparing film measurements with TPS. The phantom rod configuration was (from left to right). There is good agreement among MC, film and TPS calculations. Figure 3 shows the dose distribution and profiles 1.5 cm downstream the rod phantom for the rod configuration with air and titanium as the heterogeneities. Figure 3a) shows the SOBP dose configuration and dose profiles comparing Topas MC, film measurement and TPS. Figure 3b) shows for the Bragg Peak dose configuration and dose profiles comparing film measurements with TPS. The Topas MC data shows large spikes where the air rods were, whereas the TPS calculation shows smaller spikes in the air rod positions. The film measurements do not show these spikes, which could be due to the limitations from placing film at 0.5 cm increments.

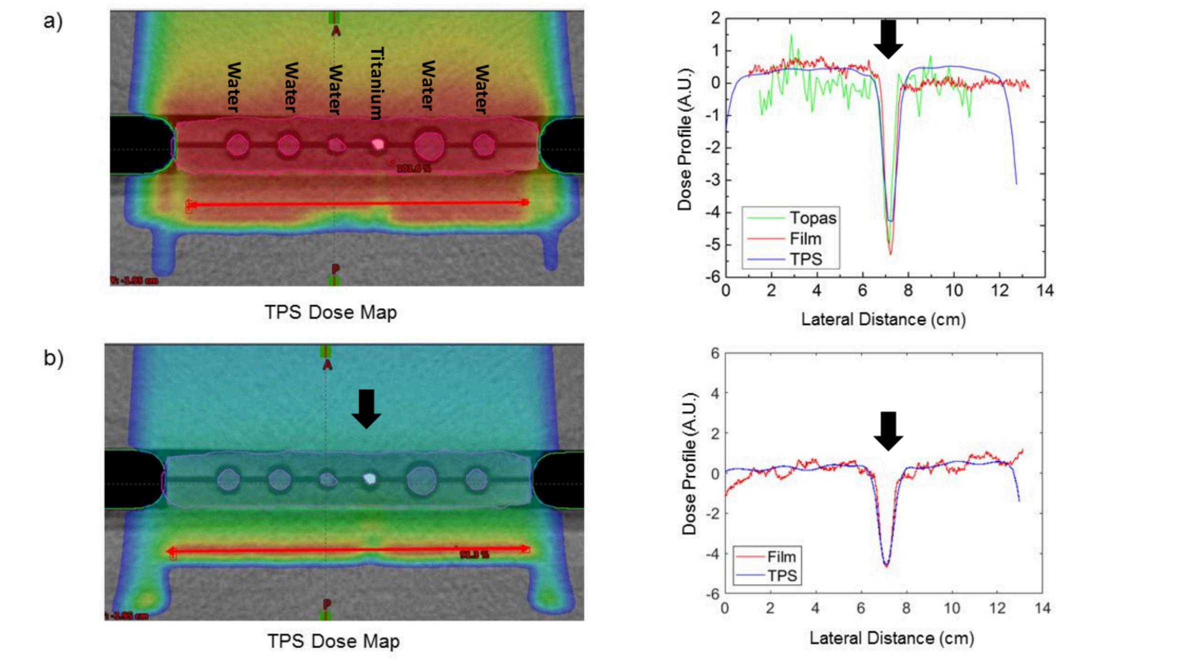

Figure 2: a) SOBP dose configuration showing TPS dose map and corresponding line profiles for Topas MC, film measurements and TPS and b) Bragg Peak dose configuration showing TPS dose map and corresponding line profiles for film measurements and TPS. Both a) and b) represent phantom rod configuration with (from left to right) water, water, water, titanium (black arrow), water, water). The horizontal red line in the dose map indicates the position of the line profile .

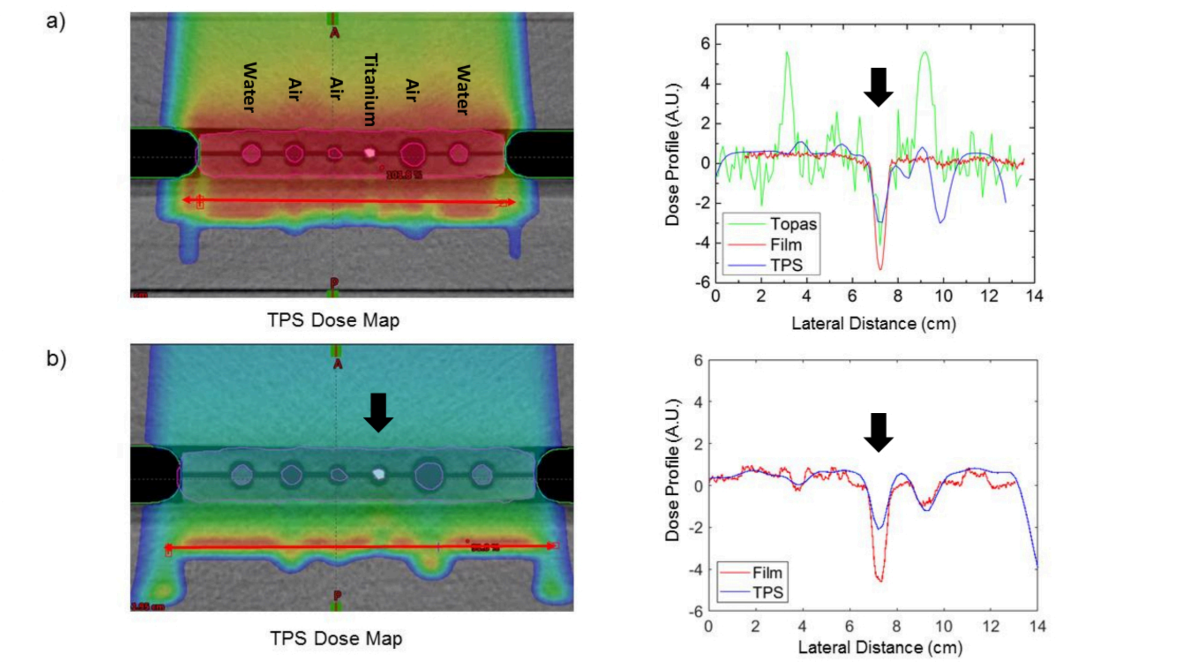

Figure 3: a) SOBP dose configuration showing TPS dose map and corresponding line profiles for Topas MC, film measurements and TPS and b) Bragg Peak dose configuration showing TPS dose map and corresponding line profiles for film measurements and TPS. Both a) and b) represent phantom rod configuration with (from left to right) water, air, air, titanium (black arrow), air, water). The horizontal red line in the dose map indicates the position of the line profile .

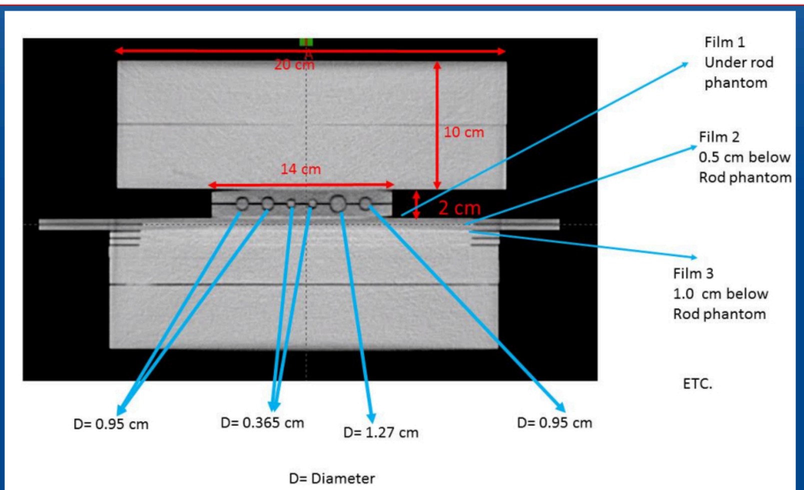

Figure 1: CT Image of Phantom Setup

CONCLUSIONS

A robust phantom was generated to evaluate the effect of heterogeneities in treatment planning systems compared to measured proton therapy beams. The phantom allows for numerous variety of interchangeable rods to evaluate various materials and sizes of heterogeneous materials. Further calculations are planned for differing rod materials to continue to validate the Proton Convolution Superposition dose algorithm. Additionally, more Topas MC calculations need to be performed to compare with the film measurements and TPS calculations.

REFERENCES

(1) Urie M., Goitein M., Wagner M., “Compensating for Heterogeneities in Proton Radiation Therapy,” PMB, 1 May 1984.

(2) Liyong L., Huang S., … Ainsley C., “A Benchmarking method to Evaluate the Accuracy of a Commercial Proton Monte Carlo Pencil Beam Scanning Treatment Planning System,” Rad Onc Phys, 23 Oct 2016.

(3) Huang S., Kang M, … , Liyong L,., “Validation and Clinical Implementation of an Accurate Monte Carlo Code for Pencil Beam Scannin gProton Therapy,” Rad Onc Phys, 11 Jan 2018.

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