Evaluation of Proton Therapy Dose Calculations in a Simple Geometrical Static Lung Phantom

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Introduction

The Imaging and Radiation Oncology Core Houston (IROC-H) QA Center is an organization committed to provide radiation oncology quality audit programs in support of National Cancer Institute (NCI)'s clinical trials. These programs help to ensure high quality data to improve clinical outcomes for cancer patients worldwide. An important part of this process is the irradiation of one the IROC's proton baseline phantoms. This project investigated the proton lung phantom specifically due to low institutions' passing rates compared to the other proton phantoms.

The motivation for this work was based on recent publications showing deficiencies in Pencil Beam (PB) algorithm as compared to Monte Carlo (MC) calculations [1-4] along with IROC anthropomorphic proton lung data. Figure 1 shows an example of this data obtained from one of the institutions' irradiations where dose profiles comparisons between PB and MC were investigated and showed MC matching the radiation delivery better. Figure 2 shows the dose distribution on the lung calculated by the PB and the MC where, again, there is an underdosing in the posterior region of the beams (red square).

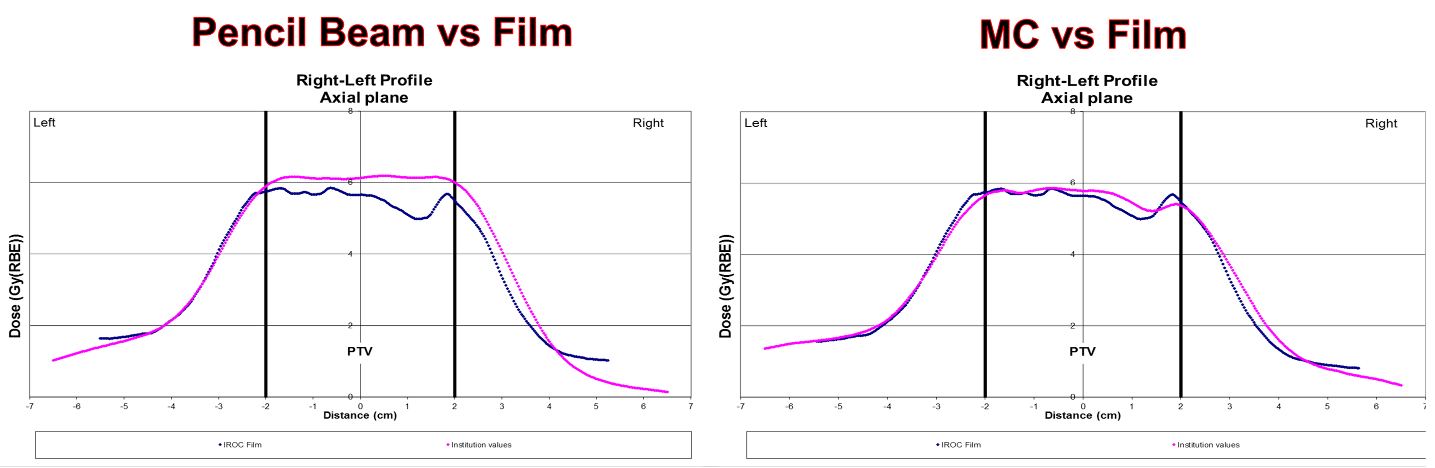

Fig 1: Example dose profiles obtained from one of the institutions' anthropomorphic proton lung irradiations with comparisons between PB and MC. MC matched the radiation delivery better than PB.

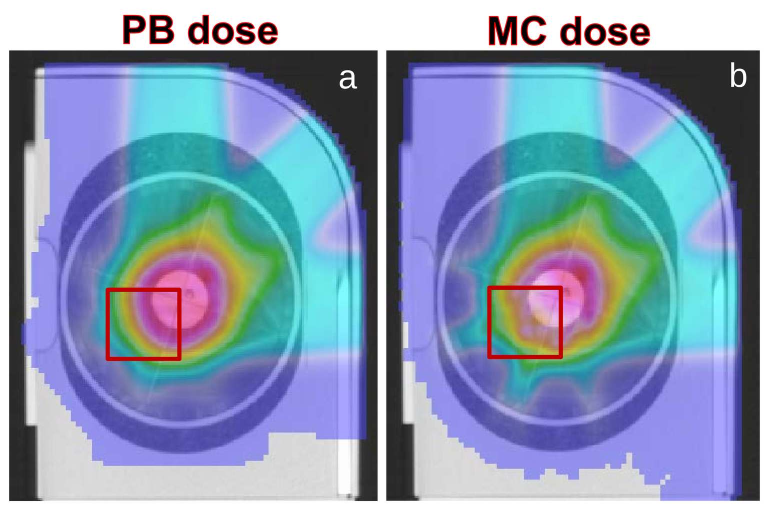

Fig 2: Dose distribution colorwash calculated using PB (a) and MC (b). Posterior region of beams is underdosed according to MC.

Materials and Methods

A geometrical lung phantom (20 cm in height, 15.5 cm in width and 10 in depth) was designed to create a simple configuration to mimic a diseased human lung (3 cm diameter cylindrical target), decoupling the motion uncertainties and bone heterogeneities introduced in the anthropomorphic IROC proton lung phantom. Solid water and balsa wood, with tissue-equivalent CT and stopping power values, were used to mimic human tissue and lung, respectively. Radiochromic film was inserted into the center of the phantom at a 5° angle with respect to both the left and the anterior wall, in order to try to minimize film quenching and streaming effects. The anthropomorphic IROC proton lung phantom and the geometrical phantom designed for this project are shown in Figure 3.

Materials and Methods (continued)

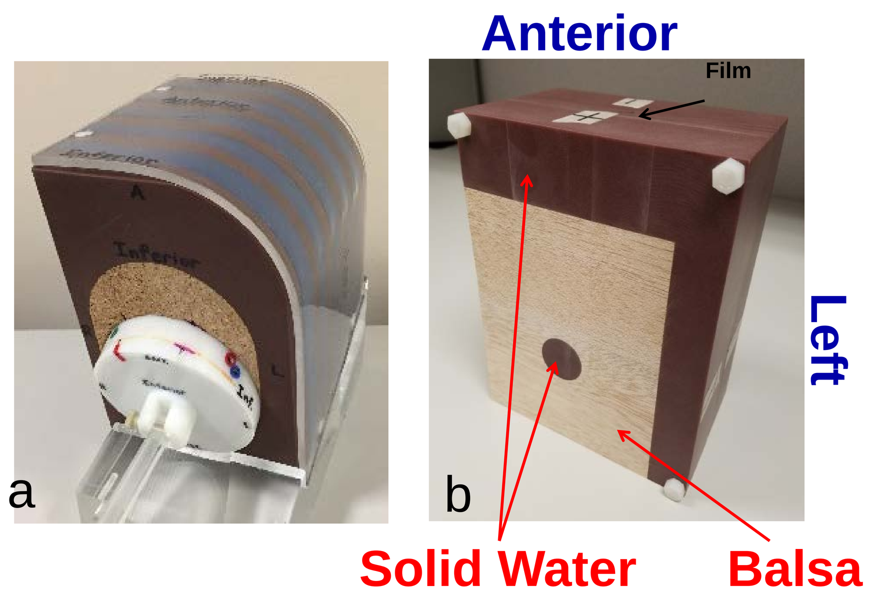

Fig 3: The anthropomorphic IROC Lung phantom (a) incorporates motion, contains a rib-like structure and has a curved surface. The simplified version designed in this project (b) was made of solid water and balsa wood and the film was angled 5° degres with respect to the anterior and left walls to help minimize quenching effects.

CT simulations were used to create proton pencil beam scanning treatment plans (6 Gy(RBE) prescription) at 3 different institutions with an anterior and a left lateral field, as shown in the screenshot of the RayStation treatment plan in Figure 4. The phantom was aligned using laser marks and onboard imaging for all 3 institutions. The measured film dose distributions were compared to each institution's clinical TPS pencil beam and MC algorithm dose calculations. Table 1 shows the planning systems and MC versions used at each institution.

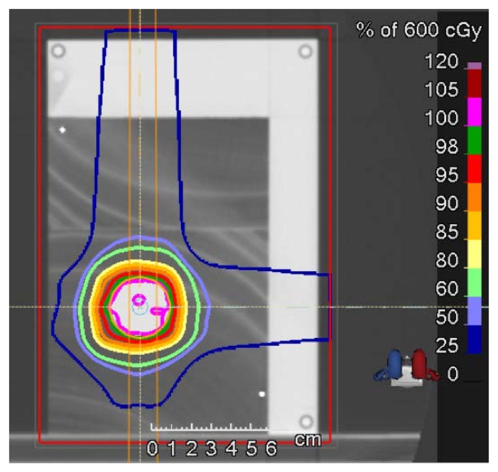

Fig 4: Screenshot of axial view of treatment plan from RayStation

	TPS	MC
Institution A	Eclipse PB	In-house
Institution B	Eclipse PB	In-house
Institution C	RayStation PB	Commercial

Table 1: Treatment planning systems and MC versions used at each institution

Results

Film profiles through the center of the target were obtained using an in-house Matlab software and compared to the planning system and MC doses for each of the 3 institutions (Figure 5). For institution A, MC agreed better with planning system except on the left-right profile where there is a disagreement in the fall off region. The disagreement could be due to poor modeling of the energy absorber used in that field, that was not used in the anterior beam. Institution B also shows better agreement between TPS and MC. However, it starts to show the pattern observed in the anthropomorphic phantom and literature where there is an underdosing in the shoulder region. Conversely, RayStation commercial MC, from institution C, agreed better with measurement, conforming to the shoulder underdosing better than TPS. For institution C, profiles were extracted from single field irradiations and also showed much better agreement between MC and film.

Results (continued)

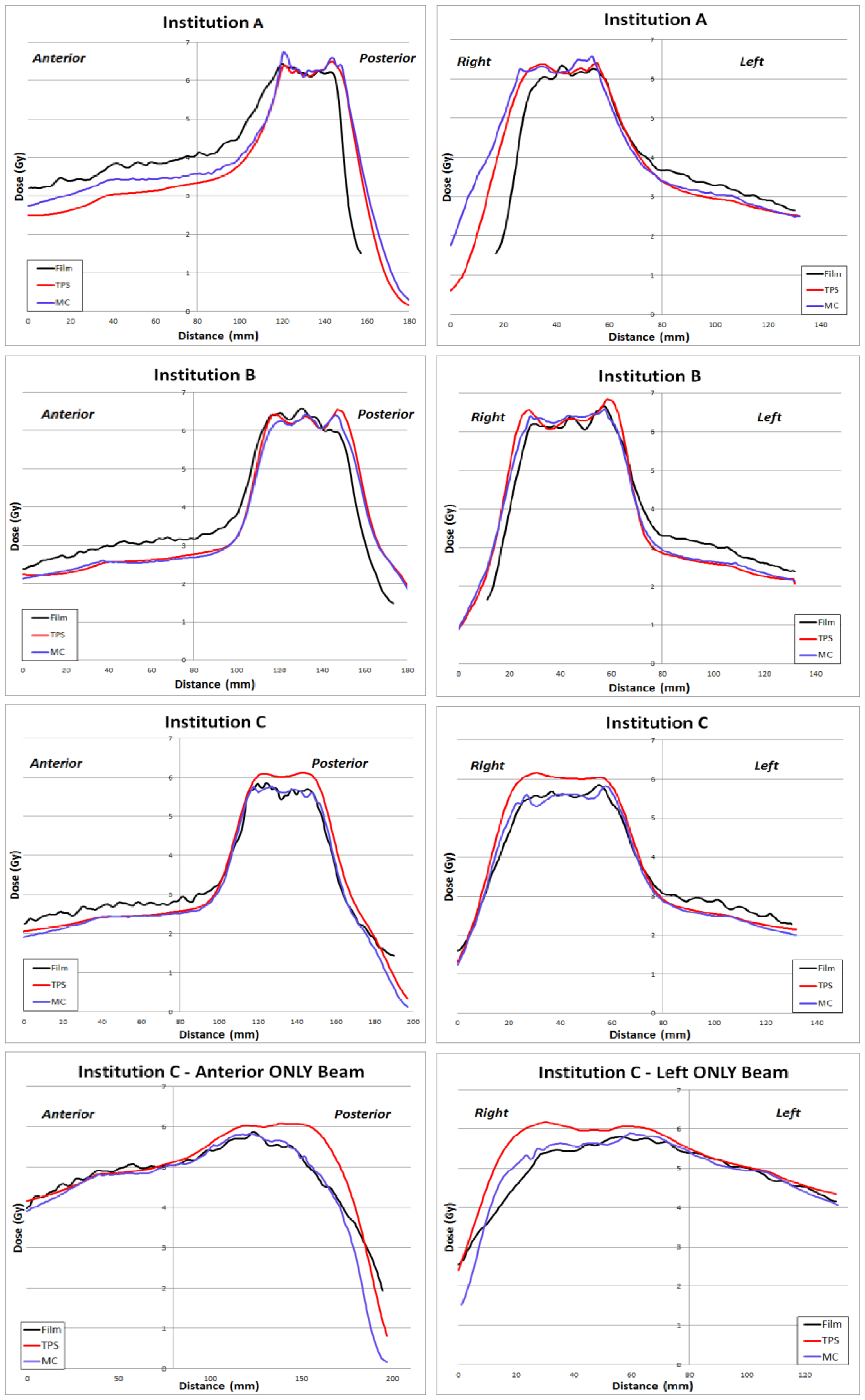

Fig 5: Anterior-posterior and left-right dose profiles across the center of the target for each institution comparing film measurement, TPS and MC.

Conclusion

In our static geometrical lung phantom, in-house MC agreed better with Eclipse TPS for institution A and B. However, institution C showed great agreement between RayStation Commercial MC and the film measurement, especially in the underdosed shoulder end.

References

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