Development of tools and methodologies for proton dosimetry audit

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Introduction

Quality assurance measures are essential within radiotherapy to ensure safe and accurate delivery of complex radiotherapy treatments. A crucial method of assessing the patient treatment is end-to-end dosimetry audit which evaluates the quality of practice across the full treatment.

Aim of work

This work contributes to proton beam therapy (PBT) end-to-end audits through the development of tools and techniques that increase the accuracy of the determination of absorbed dose.

Method

1) Investigation and formulation of proton optimised tissue-equivalent plastics (TEP).
2) Development of phantoms suitable for independent validation of range prediction and for end-to-end dosimetry audit.

Results

1) Proton tissue-equivalent plastics

A series of novel imaging photon and therapeutic proton optimised TEP were developed [1]. New materials were shown, through experiment and Monte Carlo simulation, to be superior to current commercial TEPs. The best formulations were shown to mimic stopping power, mass attenuation, and mass density within 2%, along with further reducing the uncertainty in other key radiation properties.

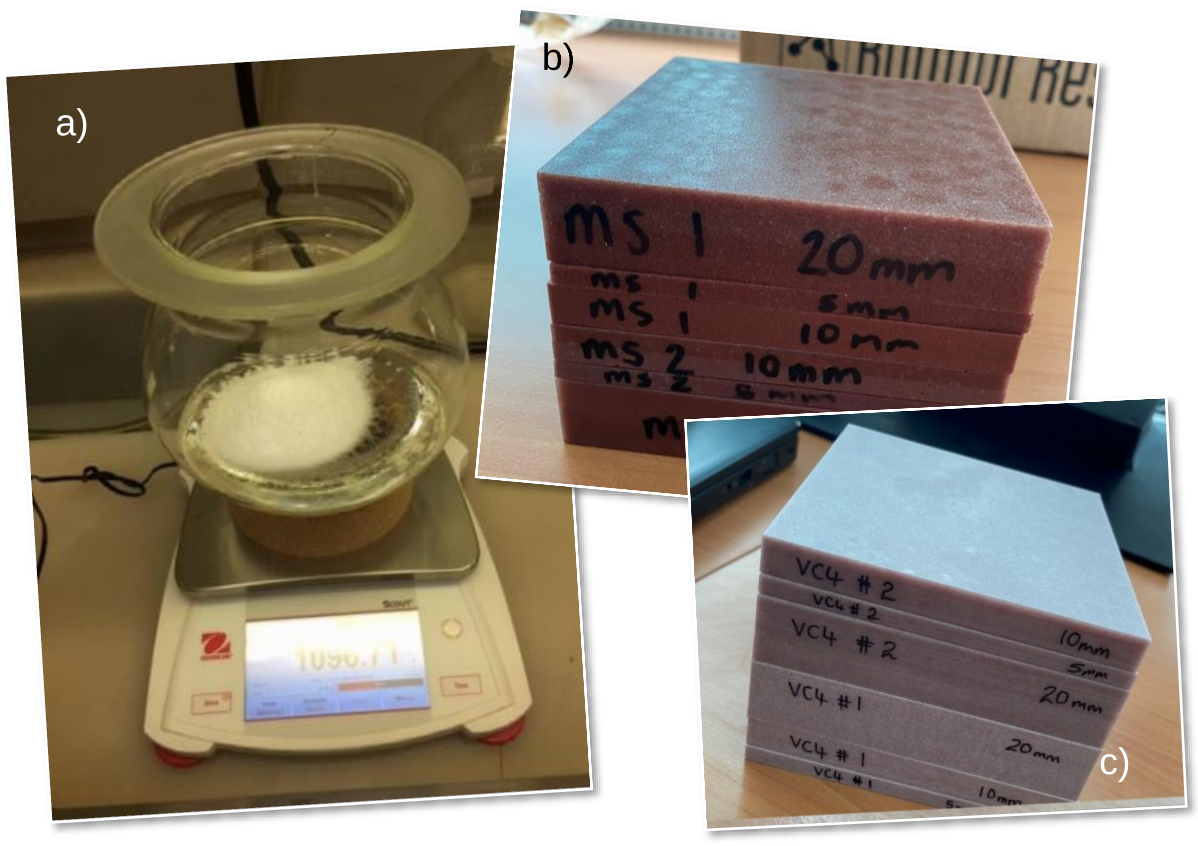

Figure 1 a) Making TEP and samples of b) muscle and c) bone TEP.

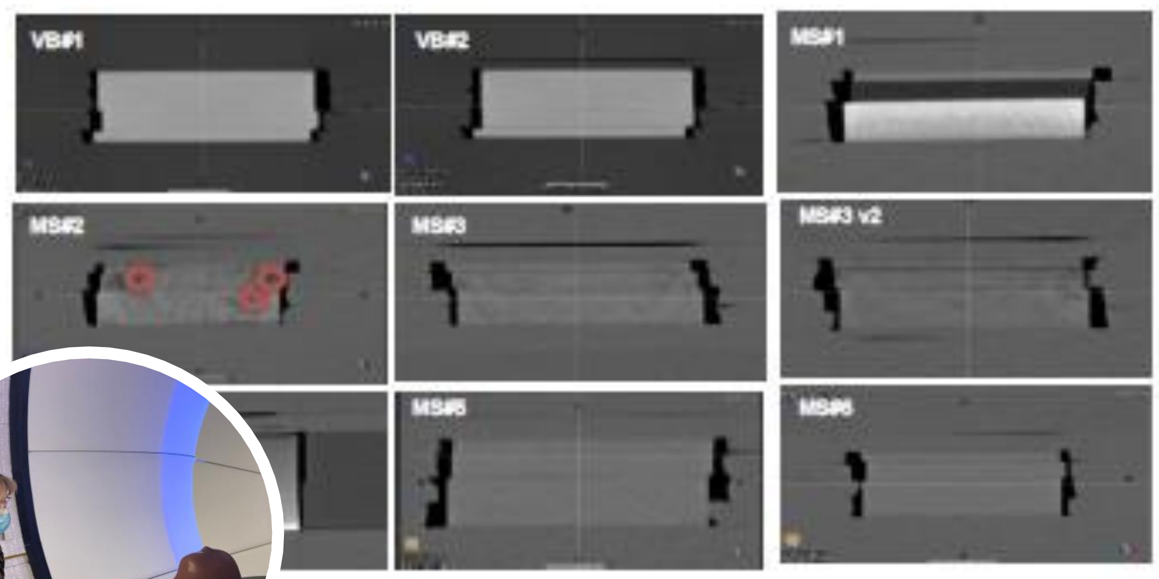

Figure 2: CT scans of sample TEPs. Red circles show air bubbles in mixture

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2) Development of bespoke audit phantoms

Two bespoke phantoms that test PBT delivery challenges were developed: Range Length Phantom (RaLPh) and PRoton heaD and NeCk Evaluation phantom (PRuDeNCE).

Challenge 1: Range prediction

The RaLPh was developed to provide independent assessment of range prediction for a series of heterogeneous scenarios (bone, lung, and solid water interfaces) in an audit setting [2]. The phantom implemented EBT3 film as a range detector (relative uncertainty of 0.5% at the R_{80}) for scanning proton beam depth dose measurements within the bespoke heterogenous phantom.

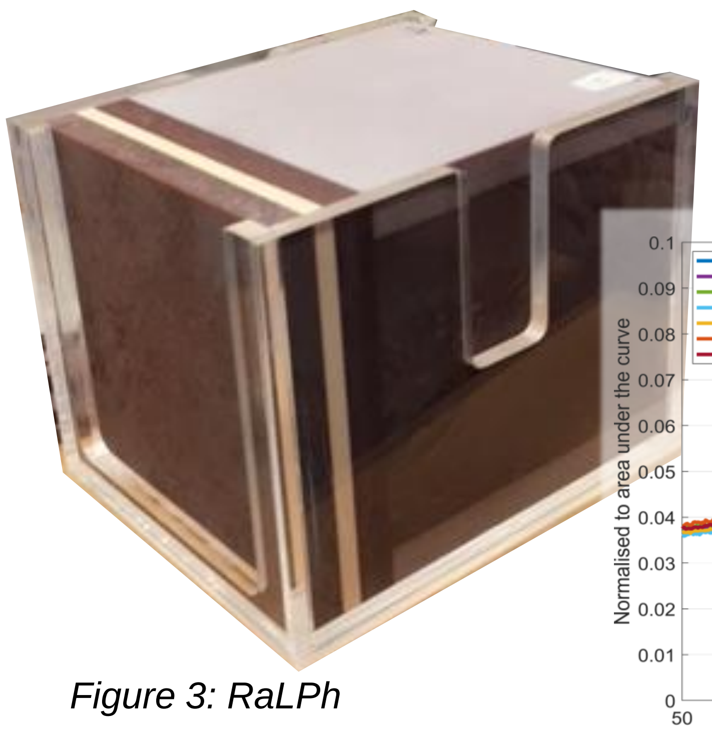

Figure 3: RaLPh

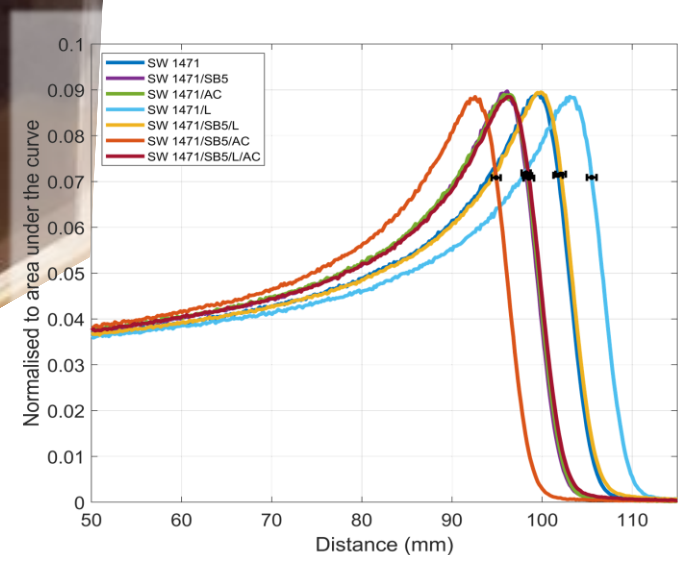

Figure 4: Average depth-dose profiles

Challenge 2: Complex head and neck treatment (adaptive planning)

The PRuDeNCE phantom was developed to evaluate PBT head and neck deliveries. It was manufactured from proton optimised TEPs and designed to be anthropomorphic in shape, with internal passive and active detectors that can be used to independently verify dose and dose distribution. Pilot results showed ionisation chamber and alanine dose measurements to be within 2% of TPS predictions with the CTV. The gamma index of film dose distribution showing a >95% agreement for a 4%/3 mm gamma pass rate [3]. It also has the capability to mimic weight loss/gain during the course of treatment.

Figure 5: PRuDeNCE phantom

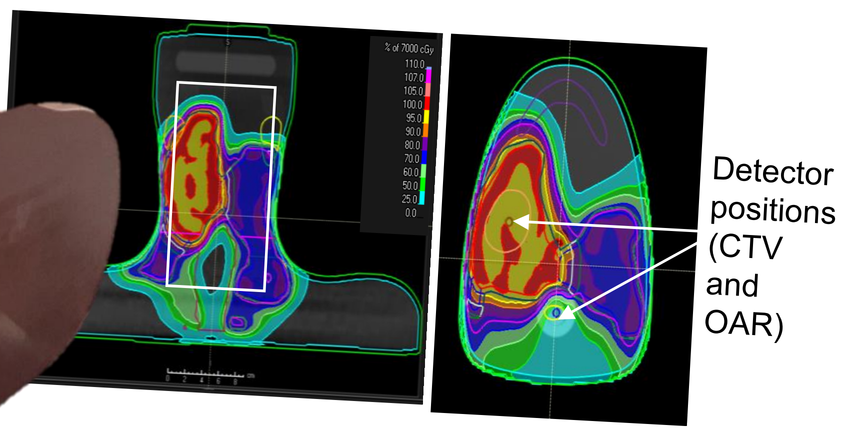

Figure 6: Example proton plan. White box is the position of EBT3 film

Project collaborators:

[1] H Cook *et al* 2023 *Phys. Med. Biol.* **68** 075009, [2] H Cook et al 2022 Phys. Med. **93** 59-86, [3] H Cook *et al 2023* PTCOG 61 P161