PhD Thesis Title: 'Incorporating Range Uncertainty into Proton Therapy Treatment Planning'

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ABSTRACT:

This dissertation addresses the issue of robustness in proton therapy treatment planning for cancer treatment. Proton therapy is considered to be advantageous in treating most childhood cancers and certain adult cancers, including those of the skull base, spine, and head and neck.

Protons, unlike X-rays, have a finite range highly dependent on the electron density of the material they are traversing, resulting in a steep dose gradient at the distal edge of the Bragg peak. These characteristics, together with advancements in computation and technology, have led to the ability to plan and deliver treatments with greater conformality, sparing normal tissue and organs at risk. Radiotherapy treatment plans aim to set dosimetric constraints, and meet them at every fraction. Plan robustness is a measure of deviation between the delivered dose distribution and the planned dose distribution. Due to the same characteristics that make protons advantageous, conventional means of using margins to create a Planning Target Volume (PTV) to ensure plan robustness are inadequate. Additionally, without a PTV, a new method of analysing plan quality is required in proton therapy.

My original contribution to the knowledge in this area is the demonstration of how site- and centre- specific robustness constraints can be established. Robustness constraints can be used both for proton plan analysis and to identify patients that require plans of greater individualisation. I have also used the daily volumetric imaging from patients previously treated with conventional radiotherapy to quantify range uncertainty from inter- and intra-fraction motion. These new methods of both

quantifying and analysing the change in proton range in the patient can aid in the choice of beam directions, provide input into a multi-criteria optimisation algorithm, or can be used as criteria to determine when adaptive planning may be required. This greater understanding in range uncertainty better informs the planner on how best to balance the trade-off between plan conformality and robustness in proton therapy.

This research is directly relevant to furthering the knowledge base in light of Her Majesty's Government pledging £250 million to build two proton centres in England, to treat National Health Services (NHS) patients from 2018. Use of methods described in this dissertation will aid in the establishment of clear and pre-defined protocols for treating patients in the future.

References to author publications that relate specifically to the dissertation:

Treatment planning optimisation in proton therapy. SE McGowan, NG Burnet, AJ Lomax. The British Journal of Radiology 86 (1021), 20120288-20120288

Defining robustness protocols: a method to include and evaluate robustness in clinical plans. SE McGowan, F Albertini, SJ Thomas, AJ Lomax. Physics in Medicine and Biology 60 (7), 2671-84