Dosimetric validation of spectral CT-based stopping power prediction for proton beams using an anthropomorphic head phantom

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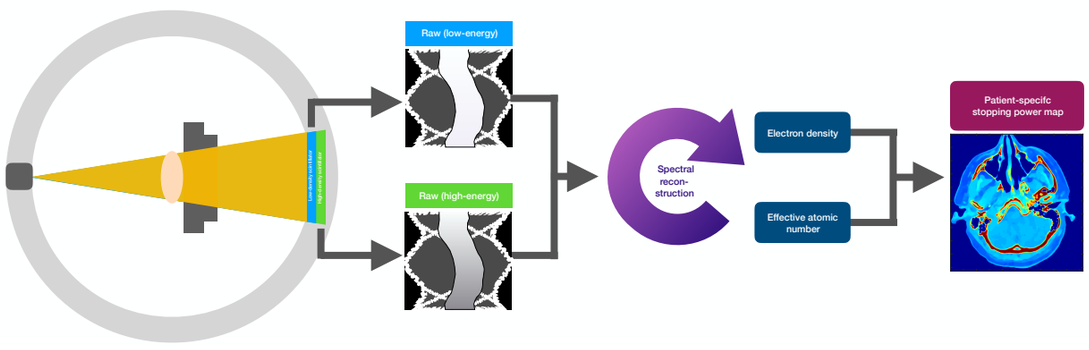
This study presents an experimental validation of stopping power ratio prediction from Philips IQon Spectral CT data, showing its benefit for improving proton therapy treatment planning.

Introduction and Objectives

We **derived and validated a novel stopping power ratio (SPR) relative to water prediction method** based on three-dimensional maps of electron density relative to water (ED) and effective atomic number (EAN) from spectral CT images covering the whole acquisition field-of-view in order to **reduce proton beam range uncertainties for proton treatment planning**.

Materials and Methods

1) Accuracy of spectral CT imaging data for planning



Principle of spectral CT-based stopping power prediction

- Spectral CT imaging based on a **dual-layer, detector-based** approach enables to directly generate spectral information without the need to pre-select specific dual-energy CT protocols
- Acquisition of calibration measurements using phantoms with various **tissue-equivalent inserts** (Gammex 467)
- Determination and comparison of SPR values **from spectral imaging ED and EAN data** following the Bethe equation and applying different approaches available in literature [1,2,3] aiming to convert EAN maps in ionization potential maps

2) Improvement of planning accuracy

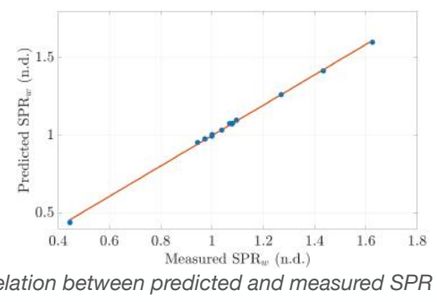
- Use of half-head **anthropomorphic phantom** (CIRS) attached to a water tank for validation in a clinical-like setting
- Performance of dose calculation for a cubic target structure on both the conventional planning CT and spectral CT to assess improvements in radiotherapy planning

CIRS anthropomorphic head phantom attached to a water tank

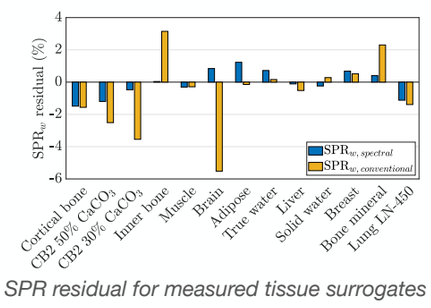
Results

1) Accuracy of spectral CT imaging data for planning

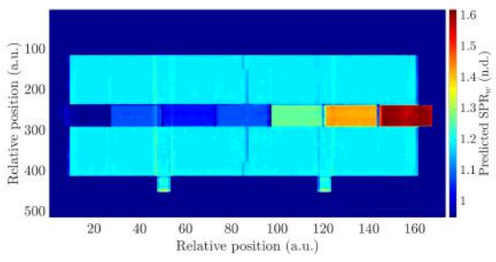
- **Calibration and validation** of 3D maps of ED and EAN from spectral CT data with phantom measurements
- **Mean accuracy of 0.6 %** for SPR predicted from spectral CT compared to measured SPR for tissue surrogates
- **Superior agreement** compared to “single-energy” CT
- Precision **unaffected** by scan settings, reconstruction parameters and phantom size



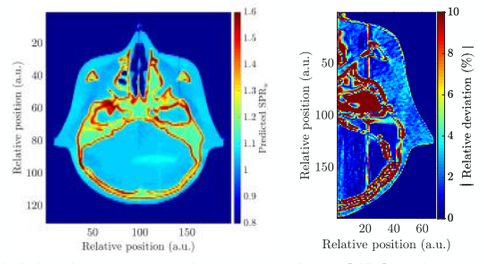
Relation between predicted and measured SPR



SPR residual for measured tissue surrogates



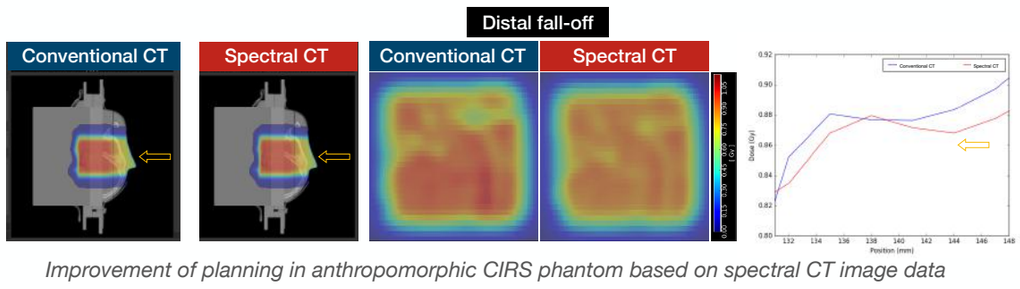
Cross-section of Gammex phantom with seven tissue-equivalent inserts showing predicted SPR



Axial plane of anthropomorphic CIRS phantom showing predicted SPR and deviation between SPR derived using conventional CT and spectral CT

2) Improvement of planning accuracy

- Mean **deviation in range** between the two calculations about 1.3(±2.6) mm using a half-head anthropomorphic phantom



Improvement of planning in anthropomorphic CIRS phantom based on spectral CT image data

Conclusions

Philips IQon Spectral CT imaging technique has the ability to **predict SPR for particle therapy more accurately** using an image-based calculation of both ED and EAN. The benefit in SPR prediction in tissue surrogates using spectral CT data is significant compared to “single-energy” CT images allowing its use to **improve range estimates in proton and heavy ion therapy**.

In **anthropomorphic phantoms**, spectral CT data promises **improvements in estimating SPR and determining range** compared to those determined by conventional CT imaging. Further comparative studies of SPR maps and range uncertainties derived from spectral CT to those determined by conventional CT imaging should evaluate its potential in **realistic patient cases**.

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References:
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[3] Möhler, C. et al. Phys Med Biol 2016; 61(11): N268-N275