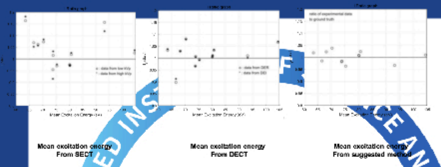

Stopping Power Estimation for Carbon Ion Beam Therapy Using Pseudo-Triple Energy CT

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INTRODUCTION & AIM

In radiotherapy, computed tomography (CT) imaging is the gold standard method to obtain patient-specific data for treatment planning. To account for tissue heterogeneities, dose calculation engines require CT calibration curves which links, in each voxel, the HU to other physical properties such as the electron density (ED) or a stopping power (SP). So called 'Schneider's method' is the most widely used calibration method in hadron therapy worldwide. However, uncertainty on HU measurements can cause tissue misallocation and yield errors on absorbed dose calculation of order of 10 % or more. Moreover, since the HU-ED(or HU-SP) relations requires performing multi-linear fits, subjectivity arises when it comes to defining the number of segments and their global trend. To overcome this current limitation, we suggest to use pseudo Triple-Energy CT (pseudo TECT), three CT images scanned with three different kVps, for more accurate stopping power estimation.

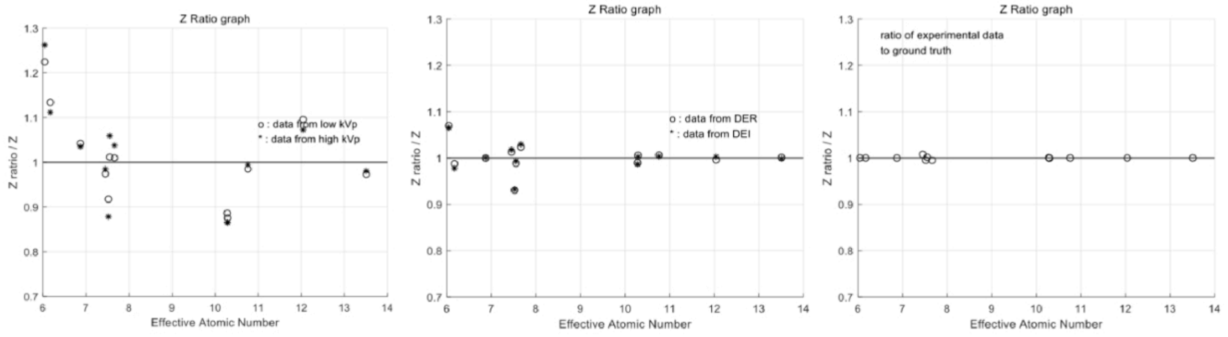
METHOD

Commercial dual energy CT scanner was used for having pseudo TECT images and Gammex 476 phantom was scanned. CT scanning with 80, 100, 120 and 140 kVp were done and all possible energy groups were tested. The core idea was inspired by stoichiometric calibration using dual energy CT-based stopping power estimation methods, then expanded and applied to pseudo TECT.

RESULTS

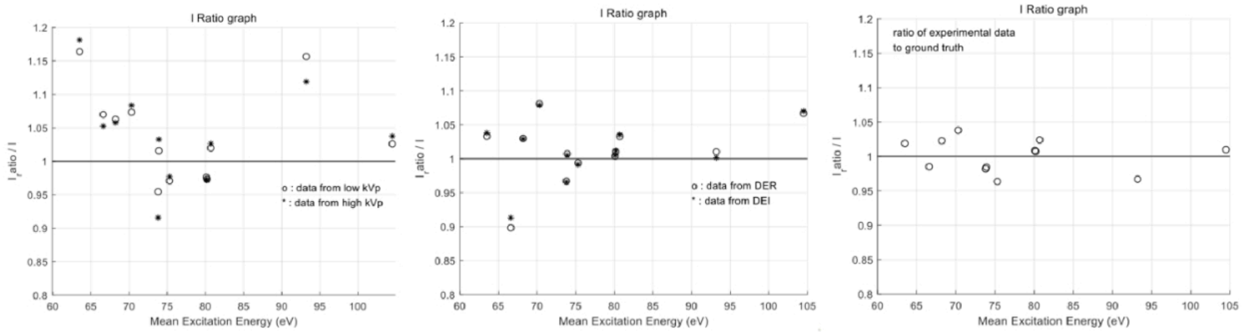
We suggest pseudo triple-energy CT (pseudo-TECT) for estimating stopping power (SP) for hadron therapy. So far, there have been many studies regarding more accurate SP estimation for proton therapy using CT images, especially using dual energy CT (DECT). This in turn implies more information can lead to more accurate estimation for SP. Therefore, here we suggest to generate pseudo-TECT by scanning conventional single or dual energy CT for multiple times. This pseudo-TECT shows significant improvements in accuracy for effective atomic number (Z) and mean excitation energy (I), which were the most challenging parts of the SP estimation for hadron therapy. We have scanned Gammex 467 phantom using commercial CT scanners and validated our methods.

Figure 1-3 show the accuracies of each variables of interest for the SECT, DECT and suggested pseudo TECT methods. As the data points are closer to the base line shown in the figures, the more precise the results are.



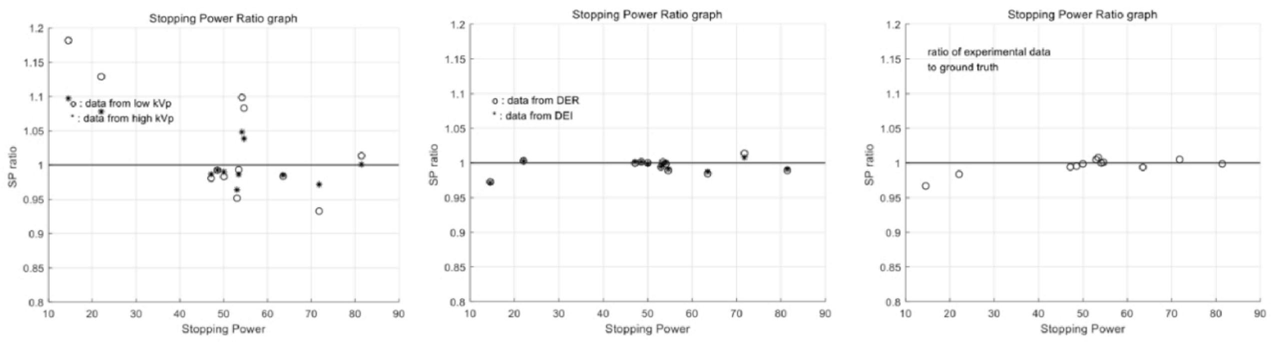
Effective atomic number From SECT | **Effective atomic number From DECT** | **Effective atomic number From suggested method**

Figure 1. Accuracies of effective atomic number estimations using SECT, DECT and suggested method



Mean excitation energy From SECT | **Mean excitation energy From DECT** | **Mean excitation energy From suggested method**

Figure 2. Accuracies of mean excitation energy estimations using SECT, DECT and suggested method



Error of Stopping Power from SECT method | **Error of Stopping Power from DECT method** | **Error of Stopping Power from Suggested method**

Figure 3. Accuracies of stopping power estimations using SECT, DECT and suggested method

CONCLUSIONS

The residuals(in %) for the estimated electron density, atomic number, mean excitation energy, and stopping power were -0.31, 0.09, 1.11, and -0.43 for DECT based estimation, whereas -0.41, 0.00, 0.10, and -0.42 for pseudo-TECT based. That is, the results were similar or worse for electron density, but extremely improved for atomic number, mean excitation energy and stopping power eventually.

Our suggested pseudo-TECT based method for hadron therapy has shown significant improvement for the accuracy of stopping power estimation compared to the DECT based method.

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