Dose calculation on dual energy CT images for carbon ion therapy using TOPAS: a Monte Carlo Study

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Background: In heavy particle treatment, since the treatment using Bragg peak is performed, accurate dose calculation is very important. Therefore, research was started to improve the accuracy of dose calculation by using dual energy CT (DECT), which is generally known to have more accurate material decomposition than single energy CT (SECT). The purpose of this study is to construct a dose calculation system based on DECT using Monte Carlo (MC) simulation code and to confirm the difference between dose calculation results of SECT and DECT.

Materials and Methods: TOPAS was used as the MC code for calculating the dose of carbon ions, and both the SECT image and the DECT image were imported into the TOPAS code. SECT was converted using an internal converter file, and DECT was converted using an in-house material converter. The 120kVp CT image of Philips IQon was used to calculate the dose for the SECT image. Also, DECT was obtained through Philips IQon, and a combination of Virtual monochromatic images (VMI) according to HU values was selected to better match the reference effective atomic number. The CT image of the CIRS 062M phantom was used for dose calculation. In addition, a 3D beam scanning system of a raster scanning method was modeled using TOPAS. Finally, dose calculations for three beams were performed for SECT and DECT images. The first Beam was a 290 MeV/u monoenergetic beam coming from the upper direction of the CT image, the second was a beam of the same quality that came from the lateral direction of the image, and finally, a $20 \times 20\ cm^2$ area was scanned using the modeled active beam scanning system.

Results: Dose calculations for SECT and DECT were performed and compared for three beam irradiation cases. During the first beam irradiation, the integral depth dose curves for the two images were compared, and the difference in range was 0.4 mm in SECT and DECT, and the difference in dose at peak was 0.5%. Second, in the lateral beam, since the beam path contains low-density materials such as lungs, the overall range is increased than in the first case. The range difference was 2.1 mm, and the dose difference at the peak was 2.8 %. In the last case, the dose calculation result using active beam scanning is shown in 2-Dimensions. As a result of comparing the doses of the two CTs, the dose difference in a specific pixel was more than twice that of the SECT. This is thought to be because the decomposition of the material for the DECT image is distorted due to the artifacts that appeared during the creation of the DECT image.

Conclusions: A dose calculation system based on DECT image was built using TOPAS code. Since there is no beam measurement data, it is not possible to evaluate the absolute dose accuracy between SECT and DECT at this time. Through this study, the difference in dose calculation between SECT and DECT could be confirmed preliminary. In the future, dose calculation will be performed on images with reduced artifacts, and verification will be conducted through measurement when the heavy particle treatment center is established.

Reference

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