Design of bi-material bolus for carbon ion therapy using dose optimization method

Yoshihisa Takada, Junichi Doi, Syohei Mizutani

Graduate School of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba, Ibaraki 305-8573, Japan

Background: Bi-material bolus was found to be useful for proton therapy to reduce dose inhomogeneity induced by a regular bolus with a complex shape [1]. We have also developed a design method of bolus using a dose optimization technique for proton therapy [2]. Now we have extended the method to design a bolus for carbon-ion therapy.

Material and Methods: The biomaterial bolus consists of Cycowood and brass. Since the probability of nuclear fragmentation is different between low-Z and high-Z materials with the same water equivalent length, the shape of Bragg curves depends on the material through which carbon ions pass. Then we have developed an accurate dose calculation model taking into account the effect by using an interpolation method based on measured data. We used a dose optimization technique to design the optimized shape of the bi-material bolus. To confirm the effectiveness of the design method, we designed and manufactured an optimized bolus (Fig. 1) using our method and another conventionally designed bolus for comparison for a target model simulating a para-spinal tumor (Fig. 2). We measured dose distribution in water of protons passing through the beam delivery devices (ridge filter with the ripple filter) of HIMAC 290 MeV/u carbon beam line and either of the two boluses using a 96-ch parallel plate ionization chamber.

Results and Conclusion: Biologically effective dose (BE dose) in the OAR for the case of using the optimized bolus was found to be less than that for the case of using the conventional bolus while BE dose distribution in the target is nearly the same for the two cases (Fig. 3). We also found that the BE dose homogeneity is improved by use of the bi-material bolus and that the BE dose calculation model reproduces overall BE dose distributions very well. The newly developed method of designing the bi-material bolus is found to be effective for improving the BE dose distribution in and surrounding the target.

References
2. Y. Takada and R. Kawai, et al.,” Optimized bi-material range compensator for an RTOG-phantom for proton therapy”, Poster presentation in PTCOG52 held in Essen, Germany in 2013, p.311.

Fig.1 Optimized bi-material bolus (front and backside views)

Fig.2 Target model simulating a tumor (green) near the spinal cord (OAR) (brown).

Fig.3 Comparison of (BE)DVH between the case of optimized bolus (red line) and that of conventional bolus (blue line). Left figure for target and right figure for OAR.