The Change of characteristic of Bragg curve by location of inhomogeneities

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Introduction

Proton beams have highly desirable depth-dose distribution for radiation therapy, mainly due to the superior conformation of the dose to the target volume. This conformation, however, is influenced by inhomogeneities placed in the path of the proton beam. Effects of inhomogeneities have been particularly concerning since the degradation of the Bragg peak curve. For the presence of inhomogeneities in the beam path, When proton beams pass through materials, the Bragg peak curve has complex changes due to multiple Coulomb scattering between inhomogeneous materials and proton beams, e.g., variation of the stopping power, dose perturbations, and shift of the Bragg peak and range. In this study, we describe our efforts to assess the influence of inhomogeneities on the Bragg curve.

Materials and Methods

The Geant4 toolkit, version 9.2 p02, was chosen as the simulation engine. Our implementation of Geant4 used a water phantom with dimesions $40 \times 30 \times 30$ cm^3 as a homogeneous structure. Materials of the phantom in the geometry were defined by NIST(National Institute of Standards and Technology) data. Physics models consist of electro-magnetic and nuclear process. All particles were tracked if the range was greater than the defined cut-off of 0.01 mm. To verify the reliability of the modeled beam, it was compared with the measured depth-doe curve for a 108.8 MeV proton beam within a water phantom.

The inhomogeneous condition was simulated according to the type, thickness, and position of materials. The set-up of inhomogeneities was composed of bone and adipose tissue that were inserted in the water phantom. The position of materials was selected at the proximal 36 % and 50 % points of the maximum dose in the Bragg curve. The bone and adipose tissue were selecte with a range of thickness from 0.1 to 1.0 cm. In addition, the energy of the proton beam was changed from 108 to 220 MeV with an order of 30 MeV. The physics model was applied equally with a homogeneous condition.

Results and Discussion

When the bone and aipose tissue were inserted in Plateau and Bragg peak region, Bragg peak position and range transferred approximately 0.8 mm for inserted bon with 1.0 cm thickness. Although there were movements of 20% and 80% points of penumbra, the penumbra width was changed within a millimeter according to inserted location of materials. Because 20% and 80% points on penumbra moved relatively similar distances. In each region, alterations of doses are shown follow figures.

Fig. 1 The difference of dose in inserted region of material, when energy of proton is fixed with 108 MeV.

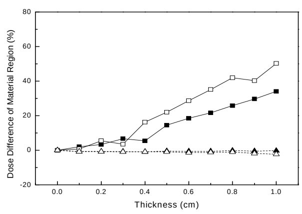


Fig. 2 The difference of dose in region of Bragg peak, when energy of proton is fixed with 108 MeV.

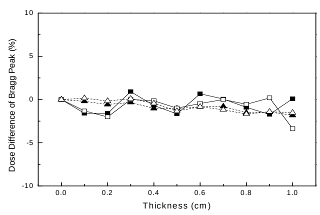


Fig. 3 The difference of dose in inserted region of material, when thickness of material is fixed with 1.0 cm.

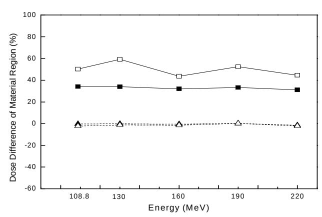
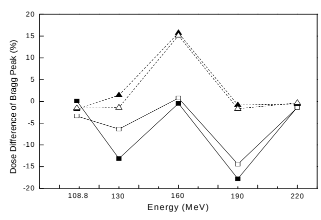


Fig. 4 The difference of dose in region of Bragg peak, when thickness of material is fixed with 1.0 cm.



From results, we demonstrated the effect on the Bragg curve by inhomogeneous materials placed in the region of the Plateau and Bragg peak, respectively. Although overwhelmingly there were no significant differences of parameters except the dose. When proton beams pass through complex geometric structures, the multiple scattering may cause a non-uniform proton fluence distribution. Inhomogeneities in the proton beam path influence energy distributions of the beam. Differences in beam composition in energy will entail different energy-loss relationships and different degrees of scattering.

Conclusions

The place of the material causes energy mixing in the penetration path of proton beams. In the clinical situation, the actual dose distribution for proton beam is less steep because of the physical character of the proton beam. This can be formally described as a convolution of the stopping power of the proton and the Gausiian distribution because proton beams pass through a complex structure within the human body. Therfore, dose perturbation by location of inhomogeneities must be sufficiently considered to achieve the purpose of proton therapy.

Reference

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