Monte Carlo simulations for the optimum design of microbeam collimator

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1. Introduction

During the last decade, radiation therapy employing microbeam has been spotlighted due to its highly enhanced therapeutic effectiveness [1]. Even though the microbeam radiation therapy (MRT) has its limitations for common use, it still arouses the interest of the researchers who look for new protocols in therapeutic radiology.

In this study, Monte Carlo simulations were performed to suggest the design criteria of microbeam collimator for better radiation treatment result.

2. Methods and Results

The peak-to-valley dose ratio (PVDR) was estimated by varying the beam width, the distance between beam centers and the collimator thickness along with different beam energies. The PVDR value is defined as the ratio of the dose delivered by the minimally scattered photons passing through the collimator opening to the one by the beam attenuated through the collimator frame. The higher the PVDR value is, the better therapeutic effect is expected in MRT. The MCNP5 code was used in computer simulations with the energy cutoff on default.

The model system, as seen in Fig. 1, consists of a 1 cm × 1 mm planar beam, a tungsten collimator and a water bath as target. The microbeam width was set at 30 μm and 60 μm. The distance between beam centers varied from 130 μm, 160 μm to 200 μm. The 1 mm-thick target was located at 1 cm below the surface of water bath. The spatial distribution of dose was estimated for the target with small divisions of 5 μm in width.

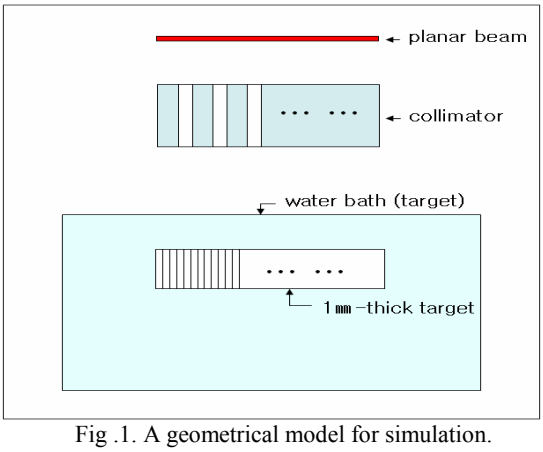

Fig .1. A geometrical model for simulation.

2.1 The change of PVDR with collimator thickness

Shown in Fig. 2 are the peak and valley doses with different collimator thicknesses for 1 MeV photon beam. The peak dose barely changes whereas the reduction of valley dose is notable with the thicker collimator. Consequently, the thicker collimator gives the greater PVDR value. The peak-to-valley dose ratios are about 1.86 with a 0.5 cm-thick collimator and about 11.7 with a 2 cm-thick one.

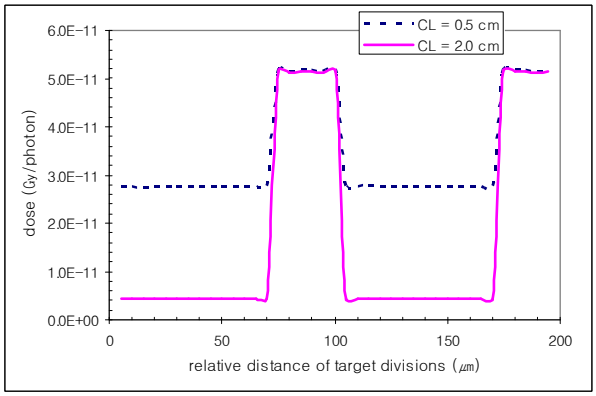

Fig. 2. The change in peak and valley doses with collimator thickness for 1 MeV of beam energy. CL denotes the collimator thickness.

2.2 The change of PVDR with beam energy

Fig. 3 informs that as the beam energy decreases the peak dose is reduced and the valley dose is reduced by even a greater degree. Therefore, the higher PVDR value is obtained with lower-energy beam. The peak-to-valley dose ratios are about 150 at 200 keV beam energy and about 1.86 at 1 MeV beam energy.

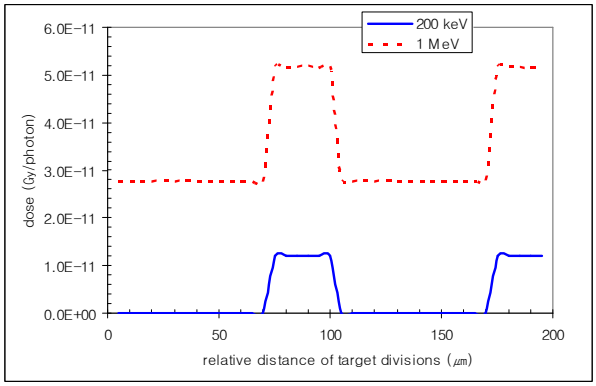

Fig. 3. The change in peak and valley doses with beam energy. The collimator thickness is 0.5 cm.

2.3 The change of PVDR with the beam width

An abrupt drop or jump in dose level at the beam edge confirms the clear-cut differentiation in energy deposition between the target and the non-target region. Little change in PVDR value has been observed for different beam widths as read in Table 1. Nonetheless, the beam width is of concern in terms of the chance of having the irradiated normal cells repaired [2].

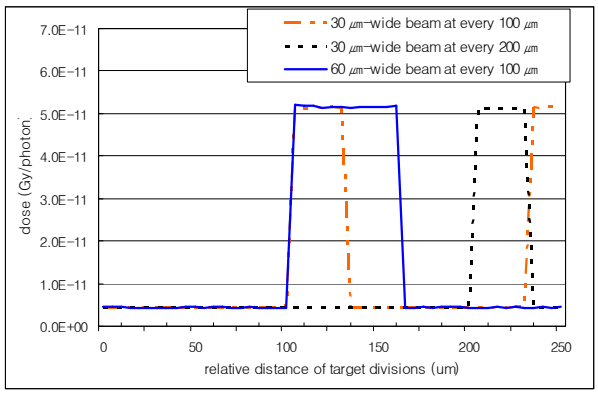

Fig. 4. The change in peak and valley doses with beam geometry for 1 MeV of beam energy. The collimator thickness is 0.5 cm.

Table 1. The values of PVDR for different beam geometries.

model cases	PVDR
30 μm in beam width, 130 μm in distance of beam centers	11.82
30 μm in beam width, 230 μm in distance of beam centers	11.83
60 μm in beam width, 160 μm in distance of beam centers	11.76

3. Conclusion

The thickness of collimator is a matter of choice not from the therapeutic effectiveness point of view any more but from the feasibility point of view in implementation of the collimator design.

The use of low-energy beam seems good not only for sparing normal cells and but also for obtaining a higher PVDR value. Still, for the treatment point of view, rather higher-energy beam is needed to have the tumorous cells killed.

If the peak and the valley doses are not significantly smeared at the beam edge, a smaller beam width is favorable for saving the normal cells. With the same distance between beam centers, normal cells have greater chance to recover with thinner beam.

REFERENCES

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[2] F. A. Dilmanian, Qu Y, S. Liu, et al. X-ray microbeams: tumor therapy and central nervous system research. Nucl Instrum Methods Phys Res A. Vol. 548, pp 30-37, 2005.