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Energy Spectrum and Angular Distribution of Stereotactic Irradiation Beam

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1 Introduction

Stereotactic irradiation using a linear accelerator has been widely adopted in many hospitals recently. For this radiotherapy technique, accurate dosimetry is important for defining the position and dimensions of the irradiation field, and determining the absorbed dose to target volume. Ionization chambers are inadequate for the measurement of spatial dose distribution because of their relatively large sensitive volumes. In the published literature, data acquisition for Stereotactic irradiation beam is mainly based on silicon diode detector, photographic film, radiochromic film and diamond detector.

In the depth-dose measurement, significant discrepancies between the reading of some silicon detectors and that of a reference ionization chamber have been reported[1]. A major cause for this uncertainty is a variation in the energy spectrum depends on depth in water. In the case of x rays emitted from a linear accelerator, the mean energy of photons will increase with depth due to the beam hardening effect. In the case that the field radius is less than the maximum range of a recoil electron in a Compton process, the result will be a lack of lower energy electrons, which travel from a distant point inside the field. Consequently, the mean energy of electrons may increase. These phenomena may affect the energy spectrum of photons and electrons as a function of depth in water.

Furthermore, Beddar has pointed out the effect of diode orientation on measured absorbed dose profiles in water[2]. This uncertainty may be due to the intrinsic detector material, detector design and a variation in the energy spectrum depends on orientation.

In this study, the energy spectrum and photons and particles (electrons and/or positrons) in water were calculated using a Monte Carlo (EGS4) simulation. The energy spectrum and the mean energy of photons and electrons were given as a function of depth and orientation.

2 Methods

The beam intensity from a clinical machine is so high that spectrometry can only be performed indirectly. Therefore, since Monte Carlo simulation can provide a highly reliable energy spectrum, several investigators have employed this method[3, 4]. We used the general purpose Monte Carlo code system EGS4[5] with PRESTA[6], and coded an EGS4 user program for this study. The energy and trajectory direction of photons, electrons and/or positrons, which pass through a sphere at arbitrary depth for an arbitrary field size, can be recorded by this EGS4 user program.

Figure 1 shows the geometrical arrangement of simulation for energy spectrum sampling. Incident photons were normally impinged to the surface of a 40 cm in diameter by 40 cm thick water cylinder. In this cylinder, imaginary spheres were arranged along the beam axis at intervals of 5 cm. The diameter of sampling spheres was 1.0 cm. The energy and direction of trajectory angle to beam axis of particle were recorded when particle passes through the sphere.

The cross section data set of water was calculated in a condition of energy cutoff parameter AE=0.521 MeV and AP=0.01 MeV, and bremsstrahlung cross section correction parameter IAPRIM=1[7] with PEGS4 as a preprocessor of EGS4. The energy spectra for a ^{60}Co unit [8], 4, 6, 10, 15 and 24 MV for a linear accelrator[9] were used in the simulation. It was assumed that the field size and field position dependence of the energy spectrum for incident photons is negligible in this study. A

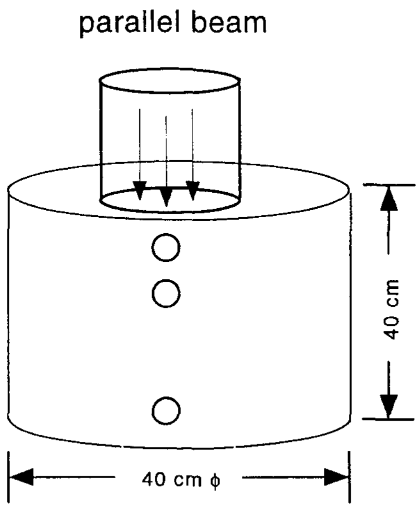

Figure1 Geometrical arrangement of Monte Carlo simulation for energy and orientation sampling

set of 1 $\times 10^6$ photons was generated per batch and 10 batches were performed. Simulations were done in a condition of transport cutoff parameter ECUT=0.521 MeV and PCUT=0.01 MeV, electron step-size limit parameter ESTEPE=0.05.

3 Results

Figure 2 shows photon energy spectra at 5 cm and 25 cm depth for a 2 cmϕ fields of 6 MV x rays. The depth dependence of the photon energy spectrum was not evident above 3 MeV. Nevertheless, it was discernible that proportion of photon below 2 MeV at 25 cm was less than that at 5 cm depth. This phenomenon may be due to the beam hardening effect.

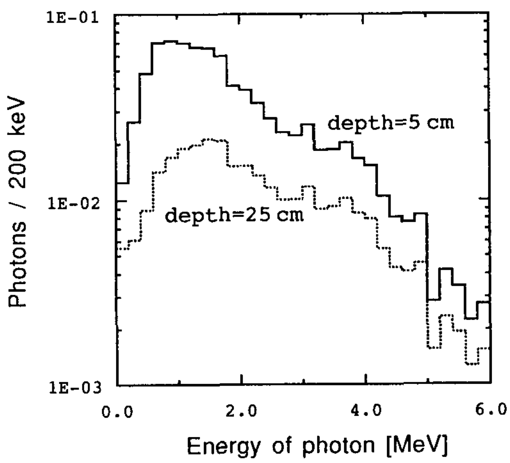

Figure2 Comparison of photon energy spectra at 5 cm and 30 cm depth for 2 cmϕ field of 6 MV.

Figure 3 shows the variation in mean energy of photons and electrons as a function of depth in water. In the case of 6 MV, the mean photon energy was 1.89 MeV and 2.34 MeV at 5 cm and 30 cm depth, respectively. The mean electron energy was 1.01 MeV and 1.15 MeV at 5 cm and 30 cm depth, respectively.

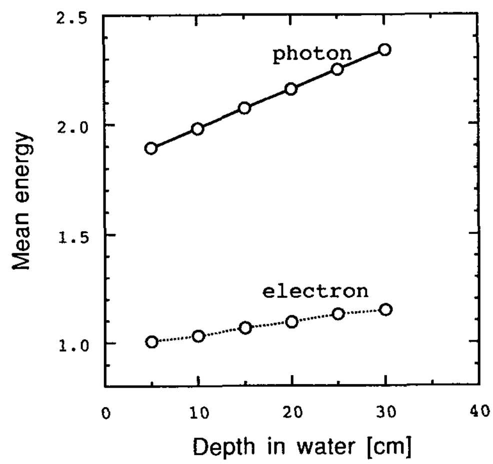

Figure3 Variation in mean photon and electron energy as a function of depth in water for 2 cmϕ field of 6 MV.

Figure 4 shows the electron spectrum in every direction and each electron spectrum in some directions. The electron energy spectrum changed as a function of direction. The electrons, which traveled in the direction of 0 -10 / 170-180 degree to beam axis, had an energy range of 0 to 5 MeV. The electrons, which traveld in the direction of 80-100, had an energy range of 0 to 3 MeV and 0 to 0.4 MeV was most prominent.

4 Conclusion

To check the variation in the stopping power ratio caused by variation in the energy spectrum, the stopping power ratios for water/silicon were determined. It was evident that uncertainty caused by a variation in the energy spectrum was less than 1% for 6 MV. Furthermore, it was suggested for a silicon diode detector that directional dependence needs to be considered.

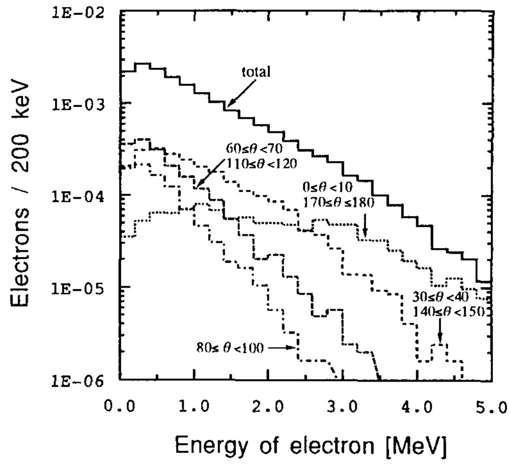

Figure4 Comparison of electron energy spectra in same directions to beam axis at 5 cm depth for 2 cmϕ field of 6 MV.

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