Estimation of Relative Biological Effectiveness for Carbon Beam

Y. Onizuka, S. Endo[1)], M. Takada[2)], M. Ishikawa[3)], M. Hoshi[3)],S. Uehara, N. Hayabuchi[4)], N. Maeda[5], K. Shizuma[1)], H. Yamaguchi[2)]

Kyushuu Univ., Hiroshima Univ. [1)], National Institute of Radiological Science[2)], RIRBM Hiroshima Univ. [3)], Kurume Univ.[4)] Izumisano Hospital[5)]

e-mail: onizuka@shs.kyushu-u.ac.jp

ABSTRACT

In this work, single event spectra were measured in order to gain the microdosimetric parameters of some heavy ion radiotherapy fields at HIMAC. Microdosimetry is now a well-established technique for the investigation of complex mixed radiation field. Changes in frequency mean lineal energy y_F as a function of thickness of A150 phantom were obtained. The absorbed dose was obtained by using y_F. A direct relation between this single event probability distribution and relative biological effectiveness (RBE) was assumed in order to estimate RBE using the response function.

Keywords: microdosimetry, relative biological effectiveness, carbon beam, Bragg peak

1. INTRODUCTION

In the radiotherapy treatment using heavy ion, physical dose evaluation is important. Knowledge on RBE ,which gives the biological dose evaluation, is more important for improvement of the therapy effect. In this work, Single event spectra of a 290 MeV/u carbon beam and secondary radiations with carbon beam were measured by an ultra miniature tissue equivalent proportional counter (UMC). A direct relation between this single event probability distribution and RBE was assumed in order to estimate RBE using the response function.

2. MATERIALS AND METHODS

UMC developed by P. Kliauga[1)] was used to measure single event spectra. The feature is that the size of measuring instrument itself is small. The main body is cylindrical geometry of 19mm diameter and 5cm length, and the mounting is possible in the human body equivalent phantom. The size of sensitive division of detector itself is also very small with 0.5mmϕ × 0.5mm. These features have been applied to measure single event spectra in the phantom.Under the pressure of tissue equivalent propane bassed gas with 760Torr, the size of the simulation 1 μm was obtained. Since

$$R_m = \int_0^{\infty} r(y) d_m(y) dy$$

the signal from UMC is the wide energy range, linear amplifier and pulse-height analyzer of 3 sets (low, middle and high amplification) were used. The measurements in total of 10 points from plateau to Bragg peak region were carried out in the biological irradiation room at HIMAC by changing the thickness of A150 plastic phantom and the binary filter made by Polymethyl Methaacrylate (PMMA) and using the ^{12}C beam of 290 MeV/u. The main deceleration board is A150, and the binary filter was used supplementary. This is for detecting secondary rays generated under deceleration of ^{12}C particle. There is a distance between binary filter and detector, when the deceleration is carried out only by the binary filter, and resulting that detection efficiency geometrically decreases. The sensitive division of UMC and the detector cylinder external wall (the A150 plastic) have coaxial relation and carbon beam was entered to detector from cylinder external wall. Measuring instruments such as tissue equivalent proportional counter made by Far West Technology Co. contain ^{244}Cm alpha source, and the energy calibration can be simply carried out. But UMC for this experiment can not contain the alpha source for the structural reason. Therefore, it was assumed that carbon beams at an energy of 278 MeV/u, after passing through the detector wall, with a stopping power value of *dE/dx*=12.2 keV// μm in water2), corresponds to a measured peak lineal energy of 18 keV/μm. The dosage was calculated with detection phenomenon number and frequency mean lineal energy. RBE Rm is obtained by weighting dose lineal energy distribution with an endpoint-specific weighting function *r(y)* determined by Tilikidis et al[3], according to the equation Where y is lineal energy, and $d_m(y)$ is the dose lineal energy distribution. It was assumed that there is the direct relation between single event probability distribution and RBE. Tilikidis et al applied the experiment (from the low to high LET region) of many different radiations to the analysis for determination of *r(y)*, in which endpoint crypt cell survival at 2 and 10 Gy absorbed dose was used.

3. RESULTS AND DISCUSSION

In figure 1, the dose probability density distribution is illustrated as a function of the water equivalent thickness. The thickness of the deceleration board is 66.32, 100.34, 130.08, 144.09, 145.09, 145.69 and 150.71 mm in the water equivalent thickness, respectively. Two distributions for thickness of 151.80 and 165.06 mm were almost equal to the distribution for 150.71 mm thickness, and they were not shown in figure 1. In figure 2, the relative dose determined with detected event number and frequency mean lineal energy was shown. The relative dose was normalized with particle number of the main monitor of HIMAC for each measurement. The maximum value was observed at 145.69 and 145.09 mm thickness in lineal energy for the relative dose and dose mean lineal energy, respectively. It was able to be decided the position of 145.09 mm, 145.69 mm or the vicinity as a Bragg peak region. The peak observed at the lineal energy from 20 to 50 keV/μm on measurements from 10.34 mm to 130.08 mm thickness was considered the contribution of carbon beam, which went through the detector. The peaks which appear in measurements over 144.09 mm thickness were terminal contribution including the fragments with high LET. Two method were processed in the calculation of RBE using r(y) determined by Tilikidis. One calculation method integrated on whole lineal energy region of the dose distribution according to the above-mentioned equation. The results were shown as *total* in the legend of figure 3 as total, and showed almost uniform on the value of RBE for all measurements. Other was integrated from the lineal energy, marked from 9 to 15 keV/μm with vertical black line in figure 1, to the infinity. The results of RBE calculation were shown as *partial* in the legend of figure 3. The reason of the division is due to be 15keV/μm for the electron edge. The spectral range larger than the lineal energy is independent of energy deposition of electron such as delta ray, etc. This divided integral enables the estimate in respect of the contribution of the region where the electron is not concerned. It was made to be 9, 10, 11 keV/μm for 10.388, 66.318 and 100.338 mm in phantom depth, respectively. For 130.084, 144.088, 145.088, 145.688, 150.714 and 151.800, 15 keV/μm was used. The results of this RBE calculation were shown in figure 2. The RBE value increased, as it goes to the beam downstream, and the peak was formed in a Bragg peak region and not remarkable as Bragg peak is. The RBE values for 150.714, 151.800 and 165.060mm depth, which is located at the downstream than a Bragg peak, was still large in comparison with the decrease in the dose. The distributions, which continued to about the proton edge 150 keV/μm on 150.714mm phantom depth (also, 151.800, 165.060 mm) , seems to be the energy deposition which concerned with the proton. In future research, it is necessary to clarify the details of the contribution to the spectrum.

4. CONCLUSION

Energy deposition spectra for carbon beam and the following fragments in the tissue equivalent phantom were measured by using ultra miniature tissue equivalent proportional counter. Microdosimetric distribution, which is closely related to the therapy effect, was obtained. Single event probability distribution was assumed to be directly related with RBE and response function obtained by Tilikidis was utilized for 290 MeV/u carbon beam from HIMAC in order to estimate RBE. The results with integration on all lineal energy turned against the prediction in the beginning, and the RBE values were almost constant. The average is 2.47 and 1.79 for endpoint of 2 and 10 Gy survival, respectively. On the other hand, RBE obtained with limited integration varied with the change of LET, and the maximum value was formed in a Bragg peak region. The value was 4.35 and 3.04 for endpoint of 2 and 10 Gy survival, respectively. And, large RBE value was kept even in the beam end part.

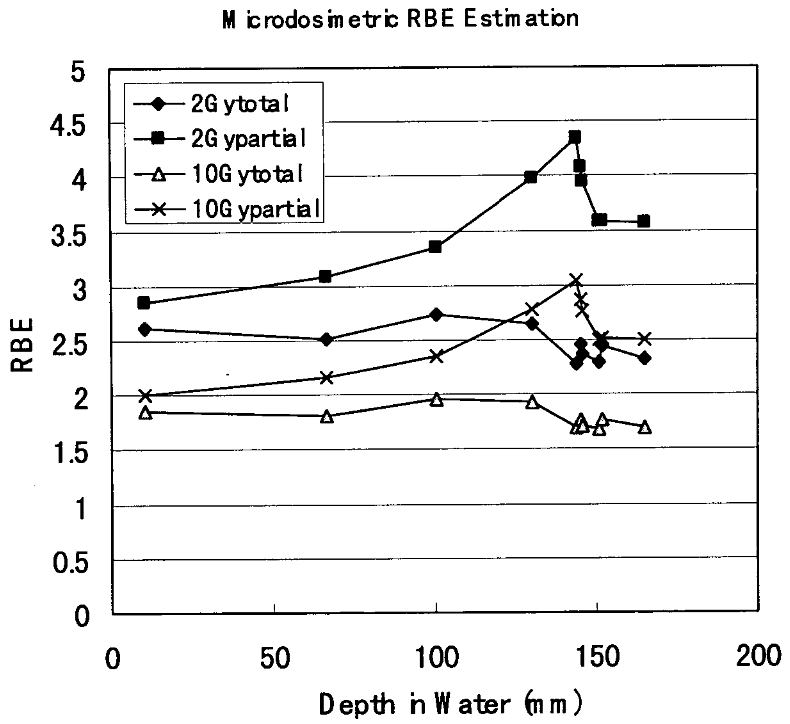

Fig 1 . Caluculated RBE values at 2 and 10 Gy for endpoint crypt cells survival as a function of water depth.

REFERENCES

1 . P. Kliauga, Radia. Prot. Dosim. 31(1/4)119-123(1990)
2 . D.E.Watt, Quantities for Dosimetry of Ionizing Radiations in Liquid Water, Taylor & Francis
3 . A. Tilikids, B. lind et al, Phy. Med. Biol. 41 (1996)55-69