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AN EGS4 MONTE CARLO USER CODE FOR RADIATION THERAPY PLANNING

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Abstract

An EGS4 Monte Carlo user code (the UCRTP code) with voxel geometry has been developed as a prototype of the dose calculation engine for radiation therapy planning. A series of dose calculations for photon beam irradiation to a simplified heterogenous voxel phantom of a lung cancer patient has shown that significant build-up in lung tumor and build-down in surrounding normal lung tissue region exist due to the heterogeneity of the media and small field size. Most of the heterogeneity correction algorithms employed by the current commercial treatment planning systems are not satisfactory enough to account for the build-up/down. Since the commercial systems may significantly underestimate the dose in normal lung tissues, sufficient verification and quality assurance of the radiation therapy planning is needed especially in the lung cancer treatment.

1 Introduction

The use of multi-modalities has enabled us to determine the volume of targets and surrounding normal tissue accurately in radiation therapy planning. Furthermore, positional accuracy has made remarkable progress recently. While such improvements of geometrical and positional accuracy have been achieved, most of the dose calculation algorithms employed in commercial treatment planning systems are still quite simple and correction methods for heterogeneity are not satisfactory since the algorithms are based on beam data in homogenous water. Currently, the Monte Carlo method is the most accurate and reliable technique for dose calculation and the outcome of the radiation therapy would be improved by using the Monte Carlo method [1,2]. On the other hand, a lot of CPU time needed to obtain statistically acceptable dose calculation results has been an obstacle to the clinical implementation of the Monte Carlo method. However, with the rapid development of computer technology, the Monte Carlo method is becoming more practical to routine treatment planning dose calculations. Sakai et al. studied dose distributions for simple heterogeneous thorax model using EGS4 Monte Carlo simulations [3]. In order to treat more realistic patient model, we have developed an EGS4 Monte Carlo user code with voxel geometry as a prototype of the dose calculation engine for radiation therapy planning. In this paper, preliminary results of dose calculations using a voxel phantom for a lung cancer patient are shown.

2 Material and Methods

2.1 Dose calculation engine

We have developed an EGS4 Monte Carlo dose calculation engine (the UCRTP code) for radiation therapy planning. This code is based on the UCPIXEL code [4] which has been used and validated for accurate dose evaluation using voxel phantoms [5]. The UCRTP code can treat voxel geometry defined by a three dimensional rectangular grids. Since the three dimensional voxel data is rather memory-expensive, The UCRTP code reads and memorizes voxel data by the GSF format [4] which can efficiently compress patient model data and reduce the required memory. This UCRTP code can model multi-port and rotational irradiation beam and the irradiation spectrum can be set arbitrarily.

2.2 Patient model

A voxel phantom of a simplified lung cancer patient model has been developed, based on the MIRD-type phantom. The voxel size is 1mm$\times$ 1mm $\times$ 1mm. This phantom consists of trunk, lungs, and lung tumor. Figure 1 shows this phantom. The lung tumor is modeled as a soft tissue sphere with the radius of 2 cm placed in a lung. The density of trunk and tumor is 0.987 g/cm^3, and that of lungs is 0.296 g/cm^3.

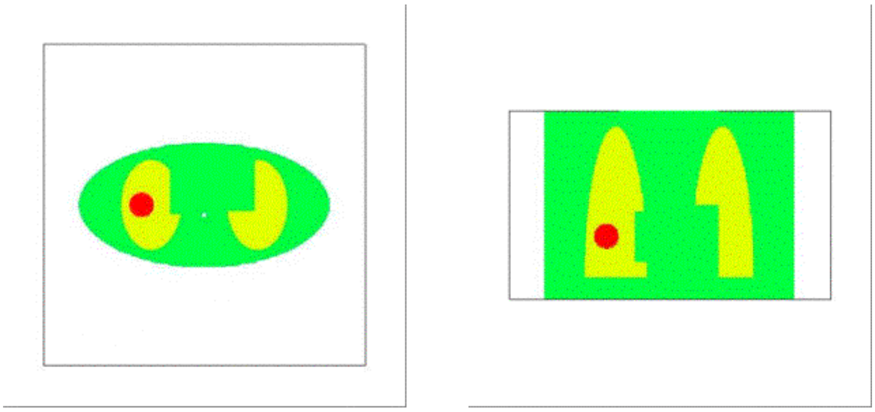

Figure 1: Lung cancer patient model based on MIRD-type phantom.

2.3 Simulations

Dose calculations have been performed using the UCRTP code and the lung cancer patient model. Single port(AP), opposed (AP-PA) and rotational parallel beam irradiation were considered. The source particle is photon with the spectrum (4,6,10,15 and 24 MV) given by Mohan et al. [6]. Figure 2 shows the Mohan spectrum. The beam radius is set to be 2.5 cm, that is, the beam has 0.5 cm margin around the lung tumor.

3 Results and discussions

Figure 3 shows the depth dose curves along the central axis for 4, 6, 10, 15, and 24 MV single port (AP) parallel photon beams calculated by the UCRTP code. We can see that remarkable build-

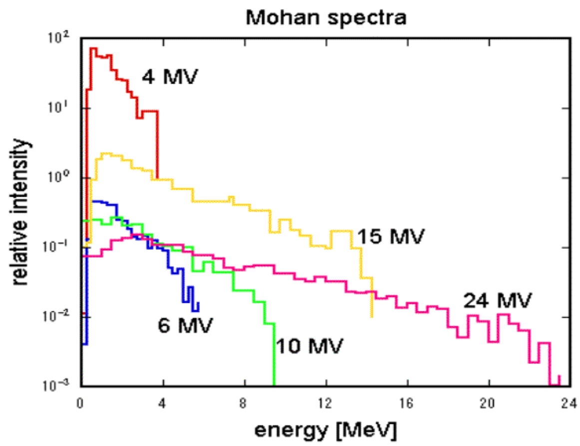

Figure 2: Beam spectrum given by Mohan et al.[6].

up exists in lung tumor and the back for high energy irradiation. This is due to the heterogeneity around the lung tumor and the secondary electron disequilibrium. For high energy photon beams, the path length of secondary electrons cannot be ignored. Figure 4 shows the depth dose curves along the central axis for 4 to 24 MV opposed (AP-PA) parallel photon beams calculated by the UCRTP code. In the same way as the single port irradiation, significant build-up in the lung tumor exists at high energies.

Figure 5 shows the dose distribution in a vertical slice at the height of tumor center for 24 MV rotational photon beam calculated by the UCRTP code. We can see that the dose distribution has a peak in the tumor. Figure 6 and 7 shows the depth dose curves along the X and Y direction on the same plane as that shown by figure 5. From figure 6 and 7, it can be seen that the uniformity of the dose distribution in the tumor is lost at high energies. The non-uniformity at high energies is due to the build-up effect in the tumor. The uniformity of the dose distribution for each energy is also compared in figure 8.

In the calculations for AP and AP-PA irradiation stated above, parallel photon beams were considered in all cases. Since the actual beam geometry is cone-like rather than parallel, the dose distribution for cone beam irradiation have been calculated. Figure 9 and 10 show the percentage depth dose curves for single port and opposing cone beam irradiation calculated by the UCRTP code. We can see that the dose is attenuated in deeper region due to the cone geometry of the beam. It can be clearly seen that not only the build-up in the tumor and the back but also the significant build-down in the lung field. The significant build-down in the lung field shown in figure 9 and 10 indicates that the simple heterogeneity correction methods traditionally used so far may significantly underestimate the dose in normal lung tissues for small field size of high energy irradiation beams.

4 Conclusion

An EGS4 user code (the UCRTP code) with voxel geometry for radiation therapy planning has been developed. Using the UCRTP code, dose distribution for photon beam irradiation to a simplified lung cancer patient model has been evaluated. Significant build-up/down of the dose distribution has been found due to the heterogeneity and the small field size. Since most of the heterogeneity correction algorithms of the current commercial treatment planning systems are not satisfactory enough to account for the build-up/down, sufficient verification and quality assurance of the radiation therapy planning is needed especially in the lung cancer treatment.

References

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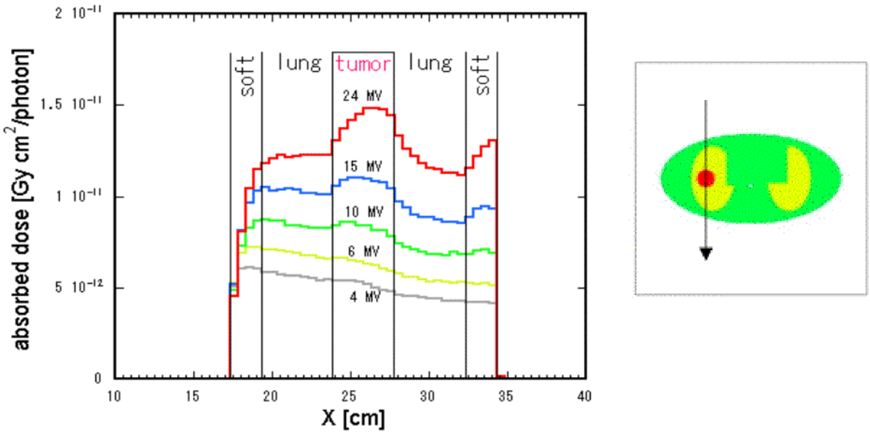

Figure 3: Dose distribution for one-prort(AP) irradiation.

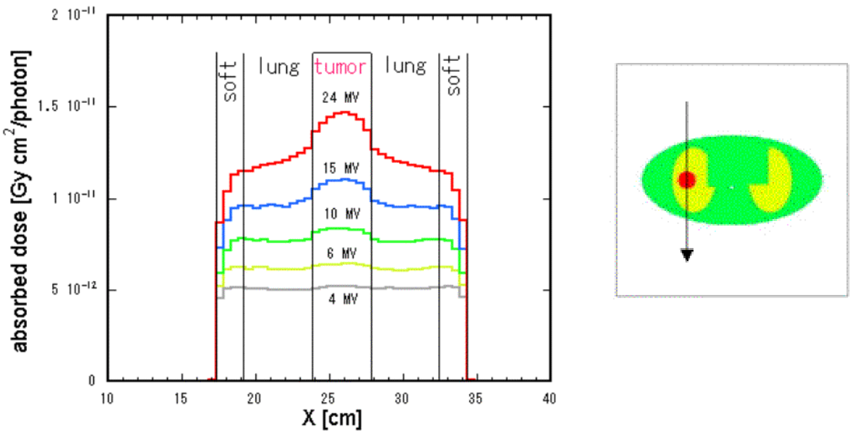

Figure 4: Dose distribution for two-prort(AP and PA) irradiation.

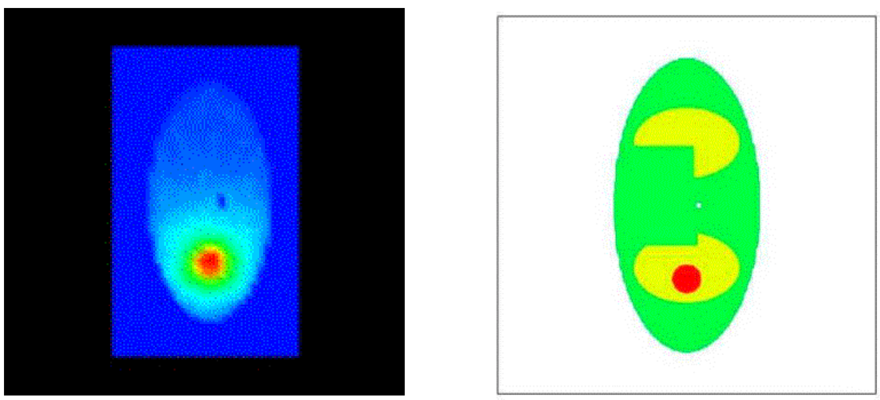

Figure 5: Dose distribution for rotational irradiation (vertical slice).

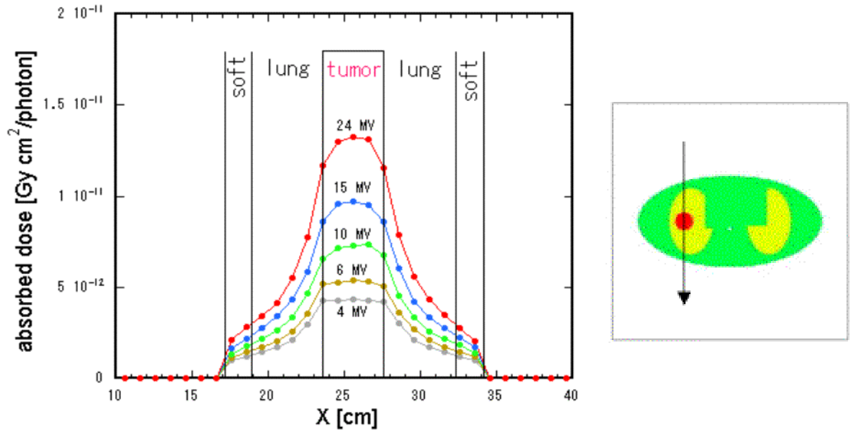

Figure 6: Dose distribution for rotational irradiation (X direction).

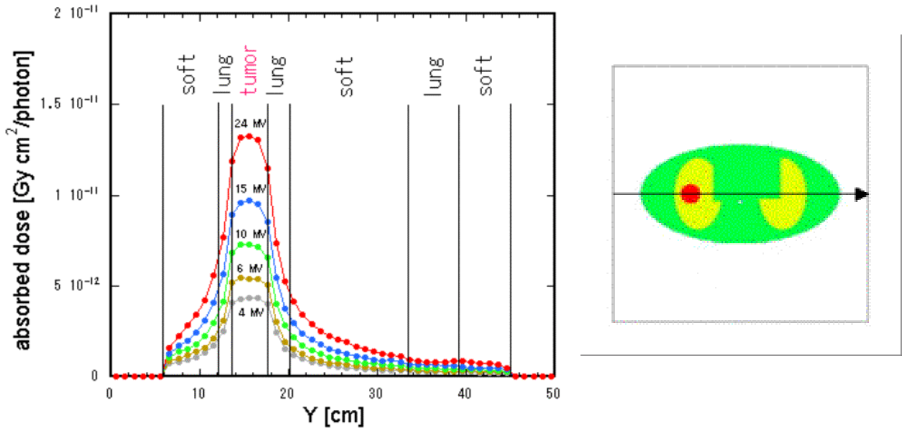

Figure 7: Dose distribution for rotational irradiation (Y direction).

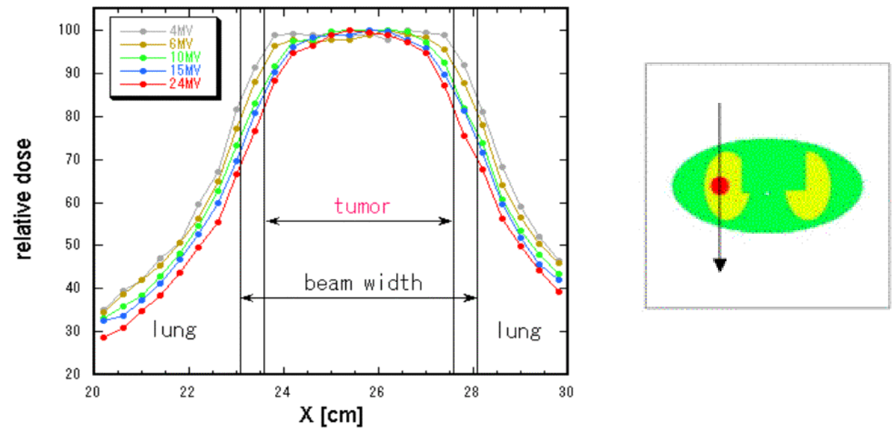

Figure 8: Dose distribution for rotational irradiation (near the tumor).

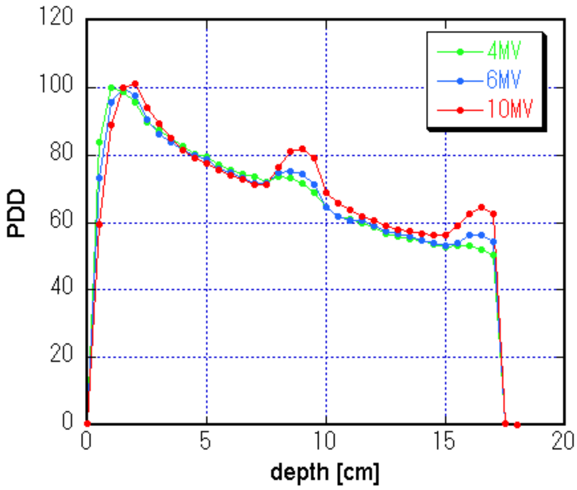

Figure 9: Dose distribution for single port (AP) irradiation (cone beam).

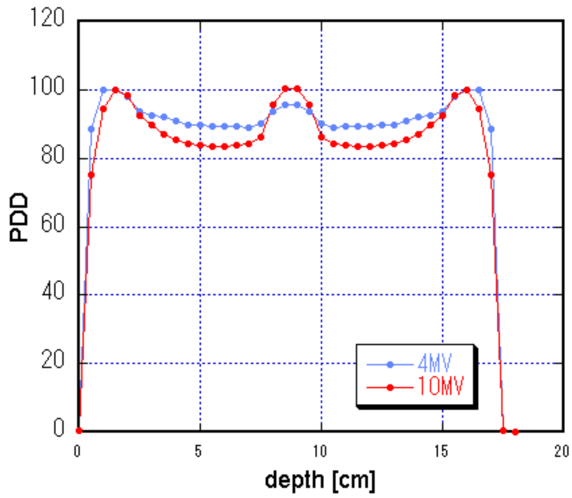

Figure 10: Dose distribution for opposed (AP-PA) irradiation (cone beam).