Photon dose calculation of pencil beam kernel based treatment planning system compared to the Monte Carlo simulation

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ABSTRACT

Accurate dose calculation in radiation treatment planning is most important for successful treatment. Since human body is composed of various materials and not an ideal shape, it is not easy to calculate the accurate effective dose in the patients. Many methods have been proposed to solve the inhomogeneity and surface contour problems. Monte Carlo simulations are regarded as the most accurate method, but it is not appropriate for routine planning because it takes so much time. Pencil beam kernel based convolution/superposition methods were also proposed to correct those effects. Nowadays, many commercial treatment planning systems, including Pinnacle and Helax-TMS, have adopted this algorithm as a dose calculation engine. The purpose of this study is to verify the accuracy of the dose calculated from pencil beam kernel based treatment planning system Helax-TMS comparing to Monte Carlo simulations and measurements especially in inhomogeneous region. Home-made inhomogeneous phantom, Helax-TMS ver. 6.0 and Monte Carlo code BEAMnrc and DOSXYZnrc were used in this study. Dose calculation results from TPS and Monte Carlo simulation were verified by measurements. In homogeneous media, the accuracy was acceptable but in inhomogeneous media, the errors were more significant.

Keywords : pencil beam kernel, convolution methods, inhomogeneity, Helax-TMS, BEAM code

1. INTRODUCTION

For the successful radiation treatment, we should deliver the exact doses to the target and spare the normal tissues from radiation hazards. Radiation treatment planning system is used for this purpose, and accurate dose calculation is very important in this step. Since human body is not homogeneous nor an ideal shape, it is not easy to calculate the accurate effective dose in the patients. Many methods have been proposed to solve the inhomogeneity and surface contour problems. Pencil beam kernel based convolution/superposition methods were also proposed to correct those effects. Nowadays, many commercial treatment planning systems have adopted this algorithm as a dose calculation engine. However their algorithm is not a full 3D dose calculation method because it takes so long time, they implement the computationally advanced method so called collapsed cone convolution algorithm. The purpose of this study is to verify the accuracy of the dose calculated from pencil beam kernel based treatment planning system Helax-TMS comparing to Monte Carlo simulations and measurements especially in inhomogeneous region. Monte Carlo simulations are regarded as the most accurate method, but it is not appropriate for routine planning yet because it takes so much time. However, Monte Carlo simulation can be used to verify the calculation results from treatment planning system.

2. MATERIALS AND METHODS

2.1 Phantom

We made a phantom which consisted of slabs of various thickness. Each slab was made up of PMMA, and some slabs contain material of low density. Cork was used to simulate the lung. Two types of phantoms were used in this study. The one type (phantom I) was what cork is the same size of acrylic slabs to get a PDD, and the other type (phantom II) is what cork was inserted inside the slabs to get isodose distributions. Cork thickness was 5cm in each phantom, and positioned from 4cm to 9cm in depth. Phantoms are shown in Fig. 1.

(a) (b) (c)

Fig.1. Two phantoms used in this study (a) slab phantom to calculate the PDD (b) coronal view of inhomogeneous phantom (c) axial view of inhomogeneous phantom.

2.2 Helax-TMS

Helax-TMS version 6.0.1 was employed in this study as a typical TPS which adopted the pencil beam based convolution algorithm as a dose calculation engine. To implement treatment plans for these phantoms, each phantom was CT scanned using AcQSim and these data were transferred to Helax-TMS. It was assumed that 6MV $10\times10cm^2$ field size radiation beam had been irradiated to the center of each phantom. PDD was obtained along the central axis of the phantom I, and profiles were obtained in phantom II.

2.3 BEAMnrc/DOSXYZnrc Code

EGSnrc based BEAMnrc/DOSXYZnrc code was used for Monte Carlo simulation. To model the Linac head, the information of the Linac head was necessary, and it could be received from manufacturer. We used Siemens Mevatron MX2 6MV machine. 2D xz view of Linac head geometry is shown in Fig. 2. The EGSnrc options and parameters used in this calculation of the phase space files were the followings : selective bremsstrahlung splitting (20-200), Russian roulette, PRESTA-I for boundary crossing algorithm and PRESTA-II algorithm for electron-step algorithm, SMAX=5cm, ECUT=0.7MeV, PCUT=0.01MeV, no electron range rejection, no Rayleigh scattering, no electron forcing. Phase space file was created for history 2.3×10^8 and the number of photon was 5.15×10^7, which was scored at SSD=100cm in the air and field size was $10\times10cm^2$. After modeling the Linac head, commissioning should be implemented. Commissioning is the step to adjust the input parameters comparing results from the Monte Carlo simulation with measurements. We had commissioned for $5\times5cm^2$, $10\times10cm^2$, $20\times20cm^2$ field sizes and SAD was 100cm in each case. Monte Carlo simulation results and measurements were agreed well in 2% error in every field sizes. Phantom was CT scanned using Siemens Somatom Plus 4 and converted to CT phantom data using CTCREAT which is included in DOSXYZnrc code. Irradiated beam conditions were the same as we had implemented in treatment plan with TMS. Monte Carlo calculation was implemented for history 3×10^8 using CT phantom data and phase space file obtained in previous steps. PDD and profiles were obtained at same position in TMS.

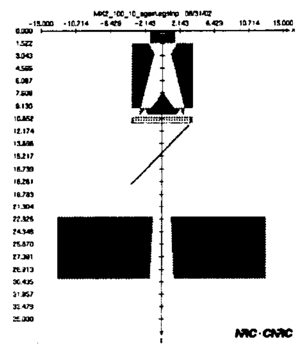
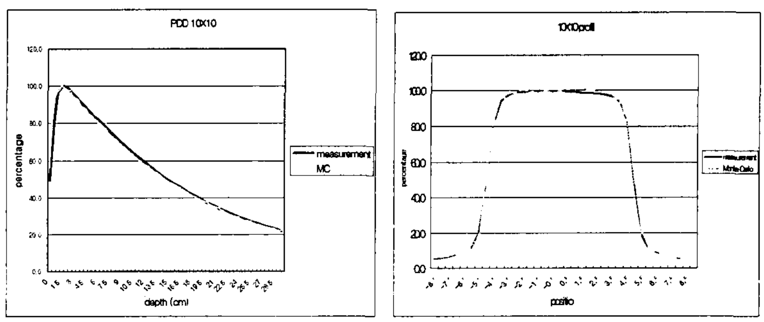


Fig. 2 Modeling of Siemens Mevatron MX2 6MV machine (lower jaw is not presented in xz view)



(a) (b)

Fig. 3 (a) PDD and (b) profile for 6MV, $10\times10cm^2$ field size at 10c depth in phantom, SAD 100cm. The solid line refers to measured dat and dotted line refers to Monte Carlo calculation

2.4 Measurements

To verify the comparison results, a few measurements were implemented. We used a Farmer chamber (PTW 30001) to measure the PDD in phantom I, and radiographic films (Kodak X-OMAT) to get a profile for axial planes in phantom II.

3. RESULTS

In PDD comparison study, the results from TMS and Monte Carlo simulation were almost same, but PDD value of TMS was slightly higher than Monte Carlo. And in heterogeneous region, TMS does not predict the effects of the inhomogeneity and error occurred up to 5. In dose distribution comparison study, isodose curve of TMS and Monte Carlo were agreed well in homogeneous region, but in inhomogeneous region, discrepancy was much greater especially in the boundary of two media and below inhomogeneous region. Discrepancy was decreased beyond the inhomogeneous region. In film measurement, dose distribution was agreed to the results of Monte Carlo simulation.

4. DISCUSSION AND CONCLUSION

Helax-TMS can correct the dose calculation result in heterogeneity by itself but still there exist error because of limits of convolution algorithm itself. In head and neck region or mediastinum region, it might be more serious than we have expected to. Though discrepancy was greater, it can be acceptable for general clinical purpose. However we can ascertain of the accuracy of the TPS, we have to study for more various conditions, e.g. various field shapes and sizes, uses of wedge or other modulator for real patient. Monte Carlo calculation can be a versatile tool to verify the accuracy of TPS.

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