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Monte Carlo Simulation of Varian Clinac 2100C Electron Beams

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ABSTRACT

Background: The purpose of this study was to investigate the application of the Monte Carlo technique to calculate and analysis of dosimetric parameters for electron beams used in radiotherapy. This technique is based on statistical method and has a powerful role in different radiotherapy aspects.

Materials and Methods: The simulated medical linear accelerator was the Varian Clinac 2100C. The electron beams 9, 12 and 20 MeV were simulated by MCNP4C Monte Carlo code. The beam geometry was 10 × 10 cm2 applicator, 100 cm SSD on the surface of homogenous water phantom. Central-axis percentage depth dose (PDD) curves and dose profile (off axis ratio) were obtained to compare with experimental measurements.

Results: The comparisons between calculated and experimental results show good agreement (within ±3%).

Conclusion: The MCNP4C code is a powerful tool for acquiring electron dosimetry results as well as other applications in radiotherapy.

Keywords: *Monte Carlo Code, Simulation, Linear accelerator, Electron beams, MCNP4C*

زمینه و هدف: هدف از این مطالعه، بررسی کاربرد مونت کارلو به منظور محاسبه و آنالیز پارامترهای دزیمتری برای پرتوهای الکترون مورد استفاده در رادیوتراپی بود. این تکنیک بر روش های آماری بنا شده است و نقش قدرتمندی را در محاسبات رادیوتراپی ایفا می کند.

مواد و روش ها: پرتوهای الکترون ۹، ۱۲و۲۰ مگا الکترون ولت حاصل از شتابدهنده خطی واریان C۲۱۰۰ در فانتوم آب همگن، با استفاده از کد مونت کارلوی MCNP4C شبیه سازی شده اند. اپلیکاتور مورد استفاده در این مطالعه دارای اندازه میدان ۱۰×۱۰ cm۲ بود. منحنی های درصد در عمقی محور مرکزی و پروفایل دز برای سه پرتو الکترون به دست آمده است.

یافته ها: با مقایسه بین نتایج محاسبه شده و اندازه گیری شده حاصل از پرتوهای الکترون شتابدهنده خطی توافق خوبی(حدود±۳٪)مشاهده شده است.

نتیجه گیری: کد مونت کارلوی MCNP4C می تواند به عنوان ابزاری قوی در دزیمتری پرتوهای الکترون بکار گرفته شود.

واژه های کلیدی: کد مونت کارلو، شبیه سازی، شتابدهنده خطی، MCNP4C

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Introduction

The Monte Carlo (MC) simulation of radiation transport is the most accurate method of predicting dose distribution and other quantities of interest in radiation treatment of patients.[1]

This technique is based on statistical method and has a powerful role in different radiotherapy aspects.

MC simulation of medical accelerators can increase our understanding of clinical beam characteristics, help accelerator design and improve the accuracy of clinical dosimetry by providing more realistic beam data.[2-3]

MCNP4C is a general purpose MC code for the simulation, which can be easily set up on personal computers, so in this study the accelerator head was simulated in one step by MCNP4C code. The aim of this work was to investigate the application of the MC technique to calculate electron central-axis percentage depth dose (PDD) and dose profile (off axis ratio) data in water phantom.

Methods

The simulated medical linear accelerator linac was the Varian Clinac 2100C. The used MC code for this simulation was MCNP4C. MCNP4C is a general purpose MC code to simulate the coupled transport of electron, photon and neutron. The various components of Varian Clinac 2100C linac were simulated. In this study the electron beams emergent from the bending magnet was assumed to be as spectrum with mono-directional shape. The geometrical model of accelerator head was made according to schemes, specially prepared by the manufacturer for purposes of MC simulation. [4] The geometrical model of Varian 2100C accelerator is shown in **Figure 1**.

The electron beams were 9, 12 and 20 MeV which was collimated by the 10 × 10 cm2 applicator in homogenous water phantom at source to surface distance, (SSD) of 100 cm. Central-axis percentage depth-dose (PDD) curves and dose profile (off axis ratio) were acquired. All experimental measurements (PDD & Profiles) data were obtained in water phantoms using PTW/Advance Markus.

The parameters of source definition included the position, charge, energy, direction and vector. The electron energy cut-off was sat to 0.5 MeV for electron and 0.01 MV for photon. All materials in this simulation concluded tungsten, beryllium, aluminum, water, ceramic, Mylar, steel and air. Depending on the incident energy, up to 100 million electron histories were considered. Central-axis percentage depth dose curves were normalized to the maximum dose value (Dmax) at the depth of maximum dose and the profiles were normalized to the value of central cell at interested depths (2.1, 2.8 and 2.4 cm). An initial estimate of the energy of the incident beam was formed using the measured value of R90, R80 and R50 (the depth of the 90%, 80% and 50% dose value on central-axis).5-6 The calculated data were compared with the measurements values.

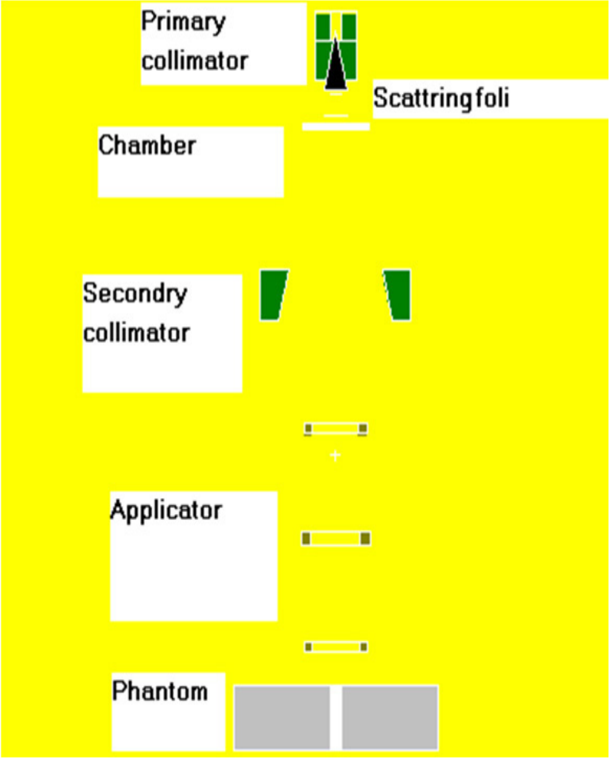

Figure 1- The modeled medical linear accelerator treatment head

Results

Figures 2, 3 and 4 show the comparison of measurements and calculated data for 3 electron beams (9, 12 and 20 MeV).

Tables 1 to 3 show different calculated and measured dosimetry parameters for field size 10 × 10 cm2. The comparisons between measured and calculated parameters show good agreement (within 2.2%).

Table 1. Measured and calculated parameters for 9 MeV electron.

	Measured (mm)	Calculated (mm)	Difference (%)
R90	30.61	30.53	0.2
R80	33.3	33.21	0.2
R50	38.97	38.37	1.51

Table 2. Measured and calculated parameters for 12 MeV electron beam

	Measured (mm)	Calculated (mm)	Difference (%)
R90	42	42.02	-0.04
R80	45.57	44.9	1.49
R50	52.91	51.45	2

Table 3. Measured and calculated parameters for 20 MeV electron beam

	Measured (mm)	Calculated (mm)	Difference (%)
R90	61.48	60	2.4
R80	72.4	70.78	2.2
R50	87	86.36	0.7

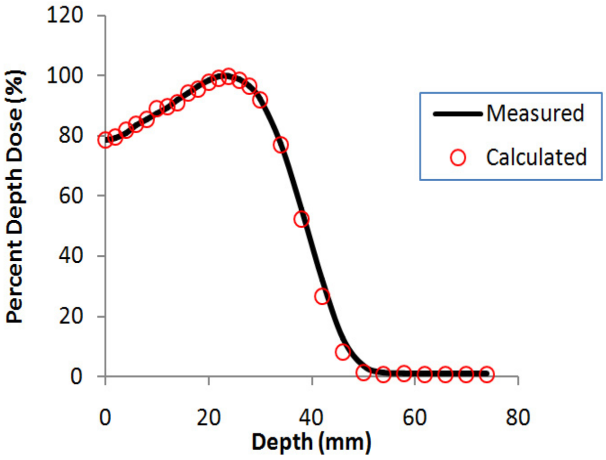

Figure 2- Calculated and measured PDDs for 9 MeV electron beam

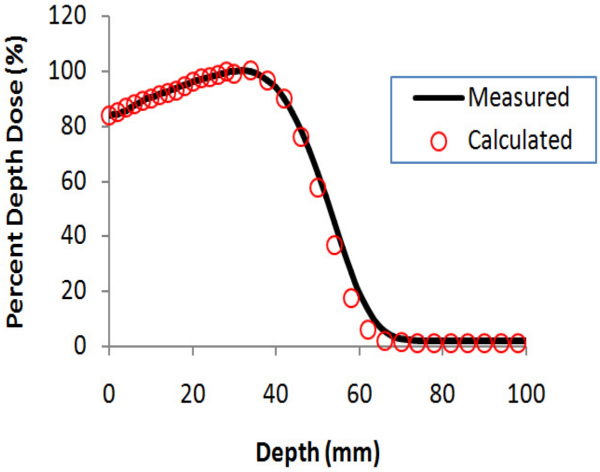

Figure 3- Calculated and measured PDDs for 12MeV electron beam

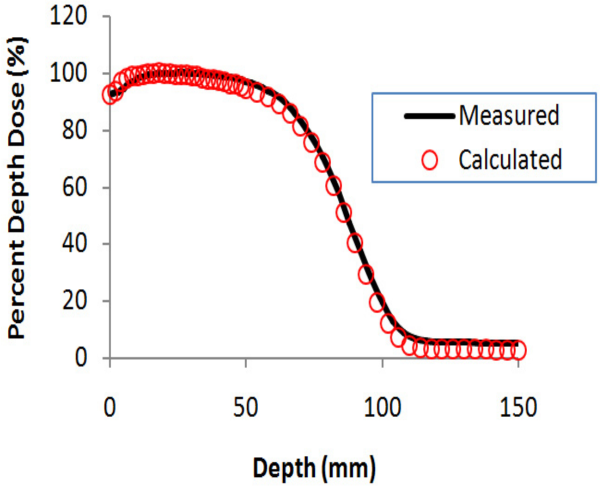

Figure 4- Calculated and measured PDDs for 20MeV electron beam

The incident electron beam energy for the profiles was adjusted iteratively until the central-axis calculated values of relative dose agreed with the measurements to within ±3% of Dmax. The statistical errors associated with the Monte Carlo calculations were in the order of 1%.

Figures 5 to **figure 7** show the MC calculated dose profiles. In figure 5 in plane dose profile at depth 2.1 cm (Dmax) is shown for the 9 MeV beam for the 10 × 10 cm2 field. Similarly in figure 6 and 7 comparisons are shown for the calculated and measured profiles at depths of 2.8 cm and 2.4 cm in water for the 12 and 20 MeV beams respectively.

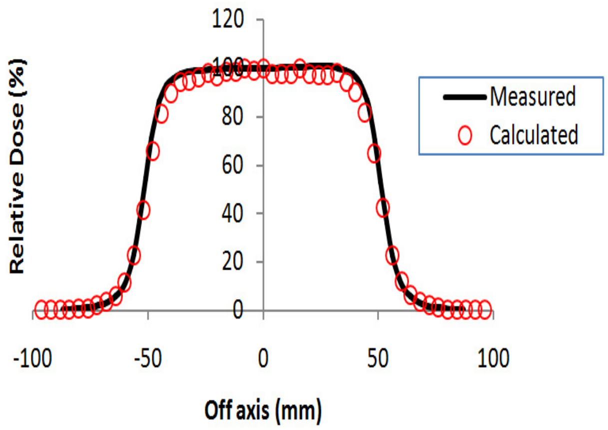

Figure 5- Calculated and measured dose profile for 9 MeV electron beam

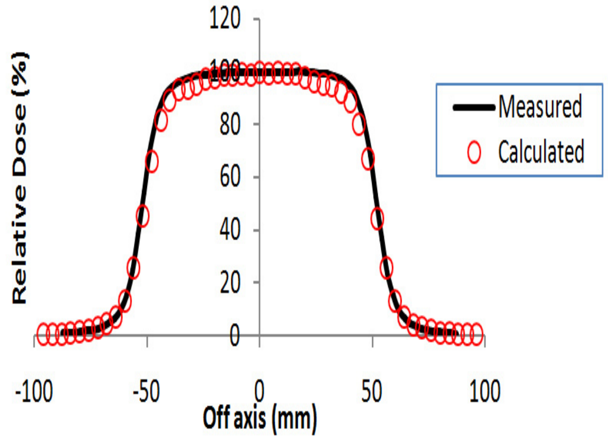

Figure 6- Calculated and measured dose profile for 12 MeV electron beam

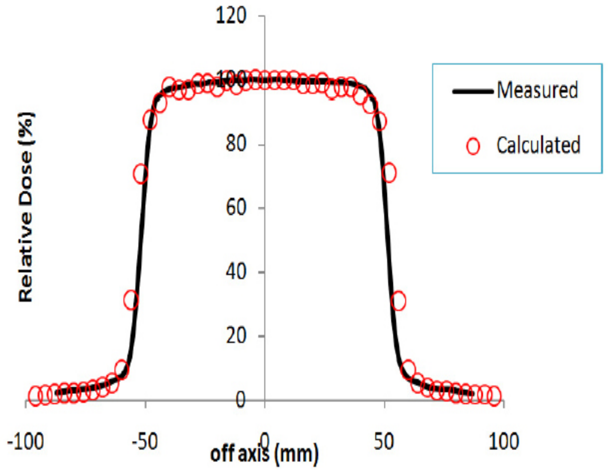

Figure 7- Calculated and measured dose profile for 20 MeV electron beam

Table 4 shows the results of difference between calculated and measured at R50 and flat regions for 9, 12 and 20 MeV electron beams.

Table 4. The results for difference of calculated and measured for 9, 12 and 20 MeV electron beams

Energy (MeV)	Difference in R50 (mm)	Difference in flat region (%)
9	0.91	2.6
12	0.93	3
20	2.2	3.1

Conclusion

The Monte Carlo can precisely analyzes the physical process involved in radiation therapy and is a powerful in dealing with any complex geometry.

The MCNP4C code is a powerful tool for acquiring dosimetry. Because the electron interaction differs from the photon interactions and also rapid fall of dose make the electron dose prediction more difficult than photon especially at borders and nonhomogeneous media. The results show MC simulation can improve the accuracy of dosimetric techniques based on dose calculations for clinical electron beams in radiotherapy.

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