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Original Research Article

Monte Carlo simulation approaches to dose distributions for 6 MV photon beams in clinical linear accelerator

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ABSTRACT

Monte Carlo method is often used in radiation therapy as utilized in all the branches of science. For this purpose, various preset codes are used for the dose calculations in radiotherapy. In this study, a new Monte Carlo Simulation Program (MCSP) was developed for the dose distributions of a clinical linear accelerator (LINAC) in water phantom. MCSP was carried out by taking into account the interactions of photons with matter in MATLAB (*The Mathworks, Inc.*). In the study, 6 MeV (6 MV photon mode) energies of photons are examined. In order to validate the performance and accuracy of the simulation, the experimental measurements and MCSP calculations were compared for both percentage depth dose curves and beam profiles. The Monte Carlo results show good agreement with experimental results.

1. Introduction

Radiation has been used frequently in diagnosis and treatment of cancer cases which has increased rapidly in recent years [1]. In calibration of radiation therapy devices, the acceptance limit values and quality control tests, which are required to determine whether the dose is to be accepted or not, are provided by the simulation techniques. Therefore, the best method is Monte Carlo method used for the dose calculations in case of very difficult experimental measurements as well as many applications. Various Monte Carlo simulation programs were often utilized on the determination of dose distributions [2,3], on effective dose estimation [4] and on calculating the scattering of photon beams [5,6]. In order to evaluate the dosimetric properties of 6 MV photon beams, Monte Carlo code systems as OMEGA [7], MCNP4C [8,9], EGS4 [10,11] and GEANT3 [12] were used. Percentage depth dose and beam profile curves were compared with Monte Carlo simulation and experimental results in a homogenous water phantom [13,14] by using single linear accelerator (LINAC) or two LINACs [15].

In this study, 6 MV photon beams of clinical linear accelerators used frequently in radiation therapy were examined. In order to validate the accuracy of the simulation, percentage depth dose and beam/dose profile curves were compared with Monte Carlo Simulation Program (MCSP) that we developed in Matlab (*The Mathworks, Inc.*) and experimental results for 6 MV photon beams.

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2. Materials and methods

The aim of a linear accelerator is to produce high energy electrons. The head (collimator) structure of Siemens Primus clinical linear accelerator is shown in Fig. 1. The head structure of LINAC consists of six major parts [16]:

- Target
- Flattening filter
- Ion chamber
- Mirror
- Jaws and multi-leaf collimator
- Reticle

Electrons, emitting as single energy beam, fall over the Tungsten target passing through exit window. Bremsstrahlung photons will be generated when electrons interact with the target [17]. A photon distribution (Bremsstrahlung photons) having continuous-energy between zero and maximum energy values (6 MeV) of incoming electrons is obtained, after they pass the target. The photon distribution is converted to more homogeneous shape by using a flattening filter for usage in clinical purposes. In order to gamma rays be followed, it should be sampled the energies, directions, free paths and the types of interaction of them. These samplings are described in the next sections.

2.1. *The sampling of gamma ray energy*

It is extremely important to know the energy spectrum of a clinical linear accelerator on the water phantom surface. The energy spectrum of the incoming photons was obtained by Mohan et al. [18] at a source to surface/skin distance (SSD) of 100 cm. Source to skin (of patient) distance (SSD) is taken as 100 cm in clinical radiation therapy applications [7,8,11,25–29].

In the study, the Mohan's photon energy spectrum was fitted for 6 MV photon beams. Mohan spectrum and fitting curve function distributions are illustrated in Fig. 2. The most appropriate fit function to Mohan spectrum was determined by,

$$f(E) = P_1 \cdot e^{-(E+P_2)^2/(2\cdot P_3^2)} + P_4 \cdot E \cdot e^{-E^2/(2\cdot P_5)} \quad (1)$$

where the parameters are calculated as $P_1 = 1.488011$, $P_2 = 3.621140$, $P_3 = 3.086142$, $P_4 = -3.804164$, $P_5 = 0.09053989$, respectively.

Basic Monte Carlo principle [19] is given by,

$$q = \frac{\int_a^x f(x)\cdot dx}{\int_a^b f(x)\cdot dx} \quad (2)$$

$$x = F^{-1}(q) \quad (3)$$

where *f*(*x*), is the most appropriate function expression for Mohan spectrum. *a* and *b* variables are the energy limit values.

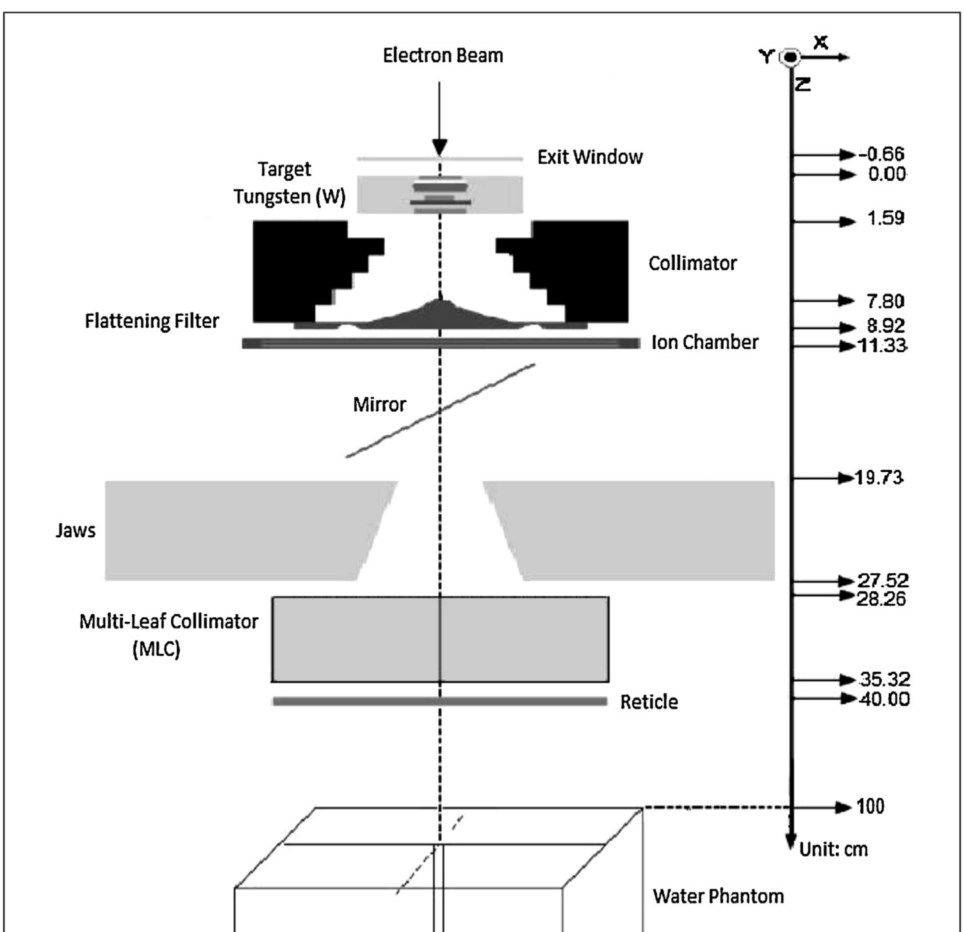

Fig. 1 – The head structure of Siemens Primus linear accelerator. This figure is not to scale.