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Evaluation of the Skin dose of 12MV Photonbeams: A Monte Carlo study

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ABSTRACT

The usage of Megavoltage beams in radiation therapy for treatment the tumors are associated (contaminated) with secondary electrons emitted from different parts of Linac head and air above the patient. The purpose of this study is to find out the effect of various physical parameters on the skin and build-up doses of 12MV photon beams generated from a Saturne43 linear accelerator, using Monte Carlo method EGSnrc. In this work we tested the value of surface dose within 1mm in water phantom. We found that the surface and build-up increasing with the field; it increases from 13.6% to 28.4% for 5×5 and 20×20 cm^2respectively. The impact of the source to skin distance (SSD) is tested. A surface and build-up dose decrease by increasing the (SSD).A surface dose decreased by 6% as we used a lead as an electron filter with thickness 0.5 mm and it reduced by 2% as air was replaced per helium column. The use of lead as an electron filter with Helium column is very important to improving the treatment and reduced the doses on a skin cells and subcutaneous.

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INTRODUCTION

Monte Carlo simulation is an accurate method in radiotherapy particularly for dose calculation and it has a significant role in optimization of the Linac head materials.

Understanding the properties (such as surface and build-up dose) of the beam in radiotherapy is an important and crucial in improving the quality and efficiency of treatment.

In radiation therapy it is better to use Megavoltage photon beams for Kilovoltage photon beams, because it has an advantage of sparing the skin of these beams. The contamination electrons accompanying the Megavoltage photon beams reduces the feature of Skin sparing [1].The highest electron surface dosecontribution at the central axis was found for the lowest energy photon beams [15].

Surface dose is a result of secondary electrons that accompany photon beams. These electrons contamination generated from the various components of the accelerator head such as target, flattening filter, collimators, beam modifiers and air volume between head and phantom or patient surface, a result of the interaction of the photons with them [1].

The amount of these contaminant electrons and low-energy photons will effect on the surface and build-up region dose [2].This effected lead to damage in the cells skin and subcutaneous.Especially that there are some areas of skin are very sensitive to the radiation therefore must be take precautions to spare it the danger [14].

The evaluation of skin dose and build-up region has an important role in the procedure of treatment [3].

Theoretically, the dose at skin surface should be neglected, but it never achieved,because there are sources of electron contamination[4].

A quantitative description of the intensity of contamination electrons produced by different components in the treatment head is difficult [5, 13].

We had a validation of this code for a Saturne43 Linacbefore doing this study.

In this work we evaluate the impact of some parameters as source surface distance, field size, replacing air by Helium and electron filter on build-up and surface dose of 12MV photon beamsgenerated from a Saturne43 linear accelerator, using Monte Carlo method EGSnrc.

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MATERIALS AND METHOD

The BEAMnrc [6]based on EGSnrcMonte Carlo code has been used to modulate and simulate the transport of particles through the head of a Saturne43 accelerator. All the materials and the geometrical data of the accelerator have been provided by the group EURADOS [7].

The components of a Linac head are target, primary collimator, flattening filter and secondary collimator (jaws). They were modulated by BEAMnrc. The phase space files were generated for each simulation.

The parameters were used in this simulation, (ECUT) cut-off energy for electrons =700KeV and (PCUT) energy for photons = 100KeV, ESAVE =1MeV (Energy below which electron will be discard in range rejection) and the forcing photons was used. All simulations were performed using 2×10^6 histories.

The DOSXYZnrc [8] based on the EGSnrc code is used toperform the simulation. For calculate the dose distributionsin a water phantom that has dimension of $40\times40\times40 cm^3$ with a source-surface distance (SSD) of 90 cm. ANon-uniform voxel size of $0.25*0.25*0.1 cm^3$ was used inour work. In this part we used the phase space files generated byBEAMnrc as sources.

The parameters were used in DOSXYZnrc, (ECUT) cut-off energy for electrons =700KeV and (PCUT) energy for photons = 100KeV, ESAVE =1MeV. All simulations were performed using 24×10^8histories.

RESULTS AND DISCUSSION

The statistical uncertainty in our calculations was 0.6%. Surface dose decreases with increasing X-Ray energy. Due to increasingthe production of low energy andelectron contamination from the air column above the patient or phantom and the components of a head.

In clinical dosimetryit is necessary to have the information about electrons contaminationpropertiesfor each systems used in radiotherapy. In this work we study some parameters effect on skin dose and build-up as field size, surface-source distance and the impact of column of air above the phantom.

1.1 Effect of field size:

Many studies[3, 9, 10, 11, and 13] have clarified the relationship between the field size and the surface dose for different accelerators. All of those studies found that the skin dose and build-upincrease with increasing field size. This increase is due to increasing the emission of secondary electrons from the air and the component of the head of Linac. In our study we found the same result. The surface dose within (1mm) in the phantom increasefrom 13.6% to 28.4% for 5×5 and 20×20 cm^2respectively,for 12MV photon beams.

Increasing of the electrons contamination with field size is due to scattered electrons and photons weak energy from the filter. On the contrary, when we use small field sizes thejaws absorb amount of weak photons and the electrons scattered from the filter.A series of studies have been mentioned in the report of (Verhaegen and Jan Seuntjens,2003). It reportedthat the reasons attributed to the filter and some of them referred to the jaws.

Figure (1) shows the build-up region for (5×5, 10×10 and 20×20 cm^2) field size at (SSD=90cm). We note that the build-up region increased with increasing field size,due to an increased the electrons contaminated.

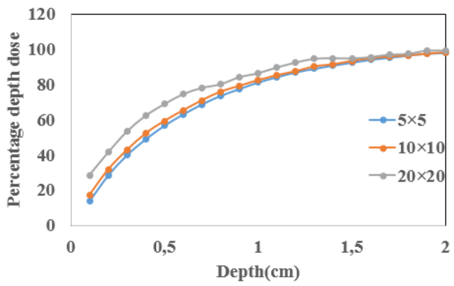

Fig. 1: surface dose as a function of field size at a constant SSD of 90 cm.

1.2 Source - Surface distance (SSD):

Figure (2) shows the relative dose at 70, 80, 90,100 and 110 cm from the target for 10×10 cm^2 open field. We observe that the surface and build-up dose decrease with increasing SSD, There is a slight variation in the values of the surface dose for a various distance (SSDs); In contrast we note clearly in figure (2)the disparities in the build-up region. This result is identical for 5×5 field.But in (20×20) field size; there is a significant change in the value of surface dose with SSDs; because of the abundance of electrons contaminated in this case compared to the smaller field. Figure (3) represents the values of surface dose for different fields (5×5, 10×10 and 20×20) and distances (70, 80, 90,100 and 110 cm). We conclude that the surface dose decreases with increasing the SSD and it increases with field size for all distances which we used in this work. Surface dose

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increases from 19.4% to 42.6% for 5×5 and 20×20 cm^2 fieldat SSD=70cm, and it increases from 18% to 33.88% for 5×5 and 20×20 cm^2respectivelyat SSD=110cm.

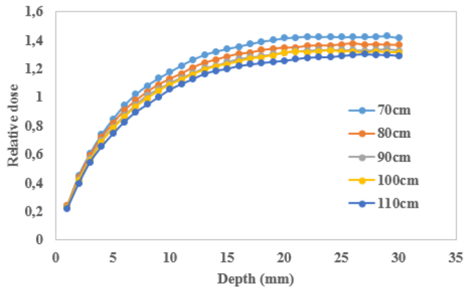

Figure 2: relative dose for differences Source –Surface distances of 10×10 cm^2field size.

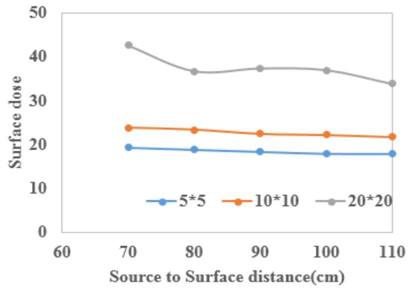

Fig. 3: Surface dose as a function in field size and SSD.

1.3 Electron generated in air:

Air column between thebelowof head the accelerator and the surface of Phantomis as a source of electrons contaminated the photon beams [1]. In this work, we study the impact of the replacement of helium instead of air column on a surface dose of 12MV photon beams for 10×10 open field. when we useda Helium gap(He),we found thatthesurface dose within 1mm in water phantom decreasedby 2%; and decreased in build-up region as shown in Figure(4). A helium is useful to sparing the skin due to decreasing the production or emission of the secondary electrons.Butson(1998) [5] found that the helium gap for 10×10$cm^2$of 6 MV decreased the surface dose by4%. Nilsson and Brahme(1979) obtained that a dose reduction of 2%–8% for 4–10 MV when they replaced the air per Helium.

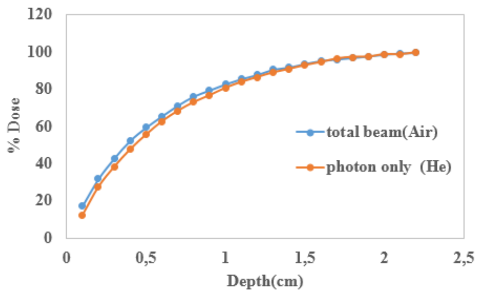

Fig. 4: Comparison between the PDD when the photon beam passes through the air and helium.

On the other hand, we comparedbetweenthe surface dosesof totalphoton beams in case of used Air and photon only (without electrons) through aHeliumcolumn between the collimators and the phantom.

In our work for 12MV photon beams, the simulate of photon beam without electrons pass through Helium columnled toreducing the surface dose by 5% for 10 ×10 cm^2 field size.

A study must be carried outin order to reach a choice of the best substance which absorbs contaminated electrons emitted from the head components.

1.4 Electron filter:

The introduction of an electron filter or the absorber(Z in the range of 30 to 80) in the photon beam ledto reduce the electron contamination generated from the head components [1].

Khan (1971) [1]found that the use of Tin at thickness, about $0.5 g/cm^2$ for ^{60}Co beams led to reduce the skin dose by 3%.

The thickness of media depends on the range of secondary electrons. We can computed the maximum range of a beta particle by the formula of Katez and Penfold [12].

$$R_{max}[g/cm2]=\begin{cases} 0.412e^{1.265-0.0954\ln(E_\beta)} & 0.01 \le E_\beta \le 2.5MeV \\ 0.530E_\beta - 0.106 & E_\beta > 2.5MeV \end{cases} \quad (1)$$

E_β is the maximum electron energy in MeV.
For calculated the thickness X:

$$X = \frac{Rmax}{\rho}$$ ρ is the material density.

A various materials as Lead, Tungsten,Silver,Goldand Aluminum were tested inthis work. It's placed at different distance from the surface of phantom. This test performed a using 20 ×20 cm^2 field size and a water phantom placed at 90cmfrom the source. We have reached that the use of lead with a thickness of 0.5mm placed at a distance of 39cm to the phantom work to reduce the surface dose by 6%.Also the replacingof air column per Helium, the skin dose reduced by ~2%. A usage of electron filter and a helium column led to reduce the skin dose by 8%.

Electron filter is useful to protecting the skin from the contaminated electron accompanying photon beam.

2. *Conclusions:*

Monte Carlo simulation is an accurate method in radiotherapy particularly for dose calculation and it has a significant role in optimization of the Linac head materials.

Possession of information about the characteristics of the beam of photons generated from any accelerator is very important to improve the quality of treatment.In this work we used BEAMnrc Monte Carlo code to evaluate and analyze the surface and build-up dose of 12MV photon beams generated from a Saturne43 linear accelerator. We found that the surface and build-up dose increase with field size due to the electrons scattered from flattening filter. The effect of Source –Skin distance (SSD) was tested. Using the helium decreases the surface dose by 2%.The use plate of lead as a filter of electrons with thickness proportional to the range of electrons reducesthe surface dose by 6%.

The use of electron filter with helium column is crucial in improving the quality of treatment and protect the skin cells from further exposure to radiation.

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