Evaluation of Electron Contamination in Cancer Treatment with Megavoltage Photon Beams: Monte Carlo Study

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ABSTRACT

Background: Megavoltage beams used in radiotherapy are contaminated with secondary electrons. Different parts of linac head and air above patient act as a source of this contamination. This contamination can increase damage to skin and subcutaneous tissue during radiotherapy.

Monte Carlo simulation is an accurate method for dose calculation in medical dosimetry and has an important role in optimization of linac head materials. The aim of this study was to calculate electron contamination of Varian linac.

Materials and Method: The 6MV photon beam of Varian (2100 C/D) linac was simulated by Monte Carlo code, MCNPX, based on its company's instructions. The validation was done by comparing the calculated depth dose and profiles of simulation with dosimetry measurements in a water phantom (error less than 2%). The Percentage Depth Dose (PDDs), profiles and contamination electron energy spectrum were calculated for different therapeutic field sizes (5×5 to 40×40 cm^2) for both linacs.

Results: The dose of electron contamination was observed to rise with increase in field size. The contribution of the secondary contamination electrons on the surface dose was 6% for 5×5 cm^2 to 27% for 40×40 cm^2, respectively.

Conclusion: Based on the results, the effect of electron contamination on patient surface dose cannot be ignored, so the knowledge of the electron contamination is important in clinical dosimetry. It must be calculated for each machine and considered in Treatment Planning Systems.

Keywords
Electron Contamination, Monte Carlo Simulation, Varian Linac

Introduction

Radiotherapy with megavoltage photon beams is one of the methods for deep tumor treatment. Skin sparing is the advantage of these beams but contaminant electrons can reduce or even diminish this property [1].

Dose at the surface is primarily due to electron contamination from the various components of the accelerator head such as target, flattening filter, collimators, beam modifiers and air volume between head and phantom surface [2].

This electron contamination can increase damage to skin and subcutaneous tissue during radiotherapy through increased dose deposition. Skin reactions such as erythema, desquamation or telangiectasia are partly due to effects of excessive doses delivered to the skin and superficial lesions.

The dose, because of electron contamination, can be measured in practical procedure using magnetic field and Helium bag. The magnetic field and Helium bag remove electron contamination due to flattening filter and air volume, respectively [3-5]. Another way for measuring the surface dose of electron contamination is Monte Carlo Simulation method [6-8] .

In clinical radiotherapy because of skin sparing of Megavoltage beams, one occasionally needs to enhance the dose near the surface. For superficial treatments, enhancing dose near the surface is necessary. Such is the function of a bolus, a natural or synthetically developed material that acts as a layer of tissue to provide a more effective treatment to the superficial lesions. So, the use of bolus affects the doses of skin and tumors that are near the surface. Using this material changes the PDD and isodose curves [9].

The problem is the existence of electron contamination doses and using bolus without calculating these for patient causing skin damage, so evaluating dose in surface and build-up region has an important role in treatment procedure.

The present study examines the sources of this contamination, the influence on the surface dose and the shape of build-up curve.

Material And Methods

In this research the MCNP-X Monte Carlo code was used to simulate the 6MV photon beam generated by Varian (2100 C/D) linear accelerator. The head components of the accelerator including target, exit window, primary collimator, Flattening Filter, ion chambers, mirror and secondary collimators were simulated based on manufacturer's data. A schematic representation of the Varian Linac head has been shown in figure1.

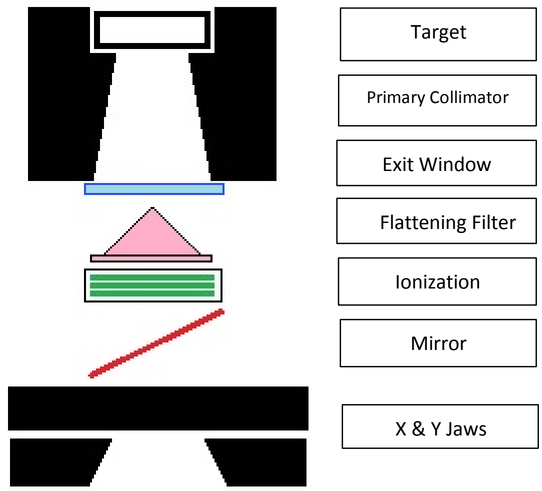

Figure 1: Linac Head Model for Monte Carlo Simulation

To compute photon beam data, a 50×50×50 cm3 Perspex water phantom (Scanditronix Wellhofer) located at SSD=100 cm was simulated.

In order to evaluate the accuracy of simulation, depth dose and dose profile curve for standard 10 ×10 cm^2 field size were calculated and compared with measured values from experimental dosimetry (error less than 2%).

Then PDD curves were calculated for different treatment field sizes (5×5, 10×10, 20×20, 30×30 and 40×40 cm^2). We named these curves total PDDs which have electron contamination too. For depth dose calculation in water phantom a cylinder (radius=0.1 field size) was defined and divided into scoring cells with 2mm height along the central axis of beam. For scoring a total of 1×108 particles by using *f8 tally were simulated.

In next step, we calculated PDD curves without contaminant electron generated by air column and flattening filter. These curves were obtained by inserting a 0.001 cm thick cell with zero importance for electrons on the phantom surface.

Electron contamination for each treatment field was derived by subtracting the total PDD curves from the PDD curves without contaminant electron. All PDD curves were normalized at the depth of maximum on central axis.

Results

Monte Carlo simulation shows that flattening filter removes produced contaminant electrons by target so the flattening filter and air are the main sources of electron contamination.

The total and without-electron-contamination Percentage Depth Doses (PDDs) curves for 6MV photon beam as a function of field size (from 5×5 cm^2 to 40×40 cm^2) are presented in Figures 2-6, respectively.

By subtracting the total PDD and PDDs without contaminant electron, the PDDs of electron contamination have been derived.

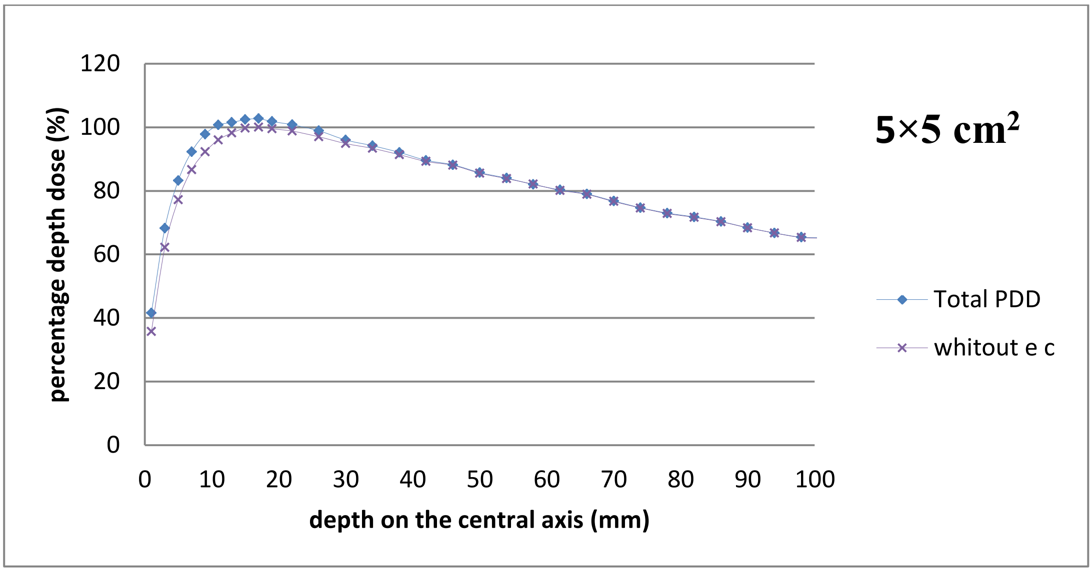

Figure 2: Total PDD and PDD without Electron Contamination for 5 × 5cm^2 Treatment Field Size

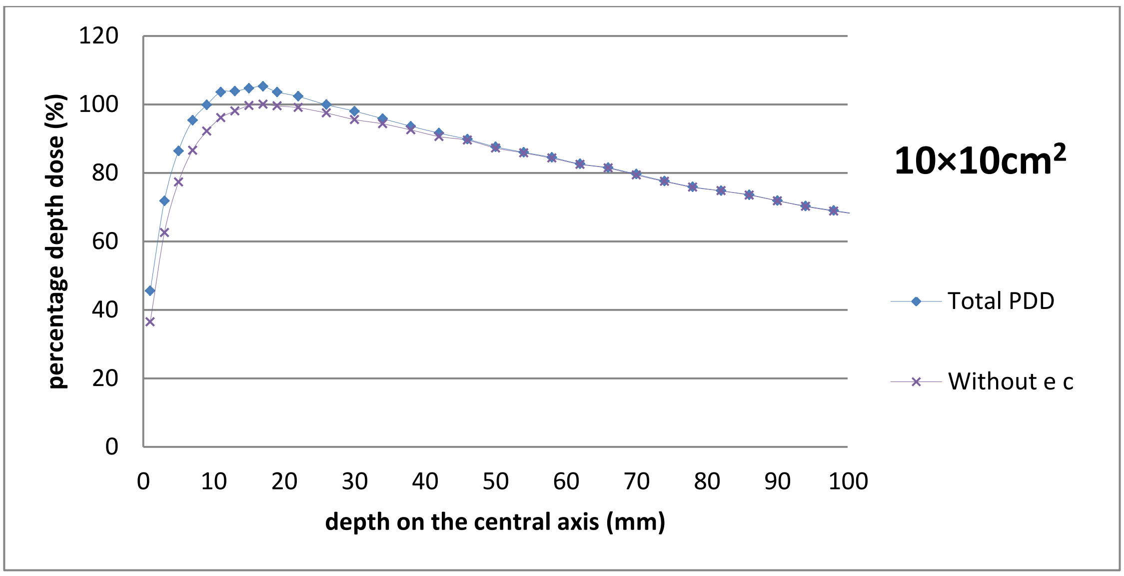

Figure 3: Total PDD and PDD without Electron Contamination for 10 × 10cm^2 Treatment Field Size

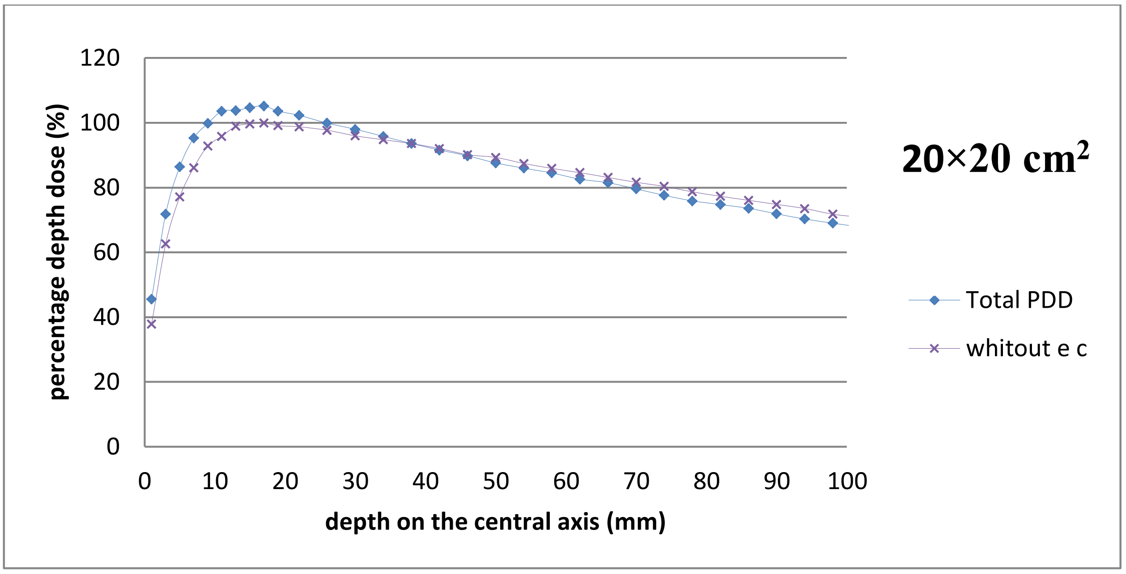

Figure 4: Total PDD and PDD without Electron Contamination for 20 × 20cm^2 Treatment Field Size

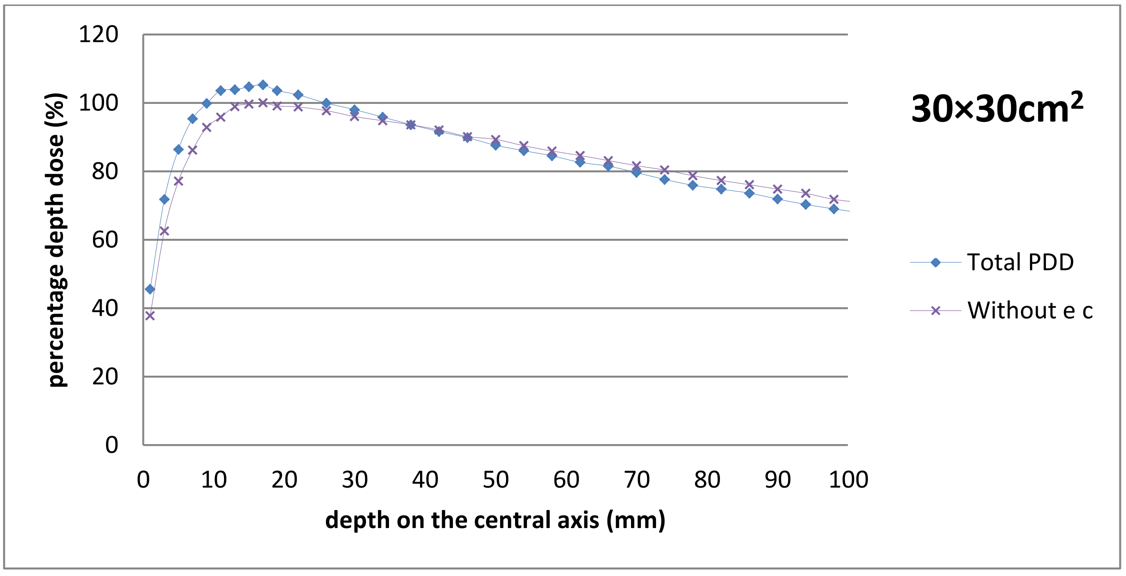

Figure 5: Total PDD and PDD without Electron Contamination for 30 × 30cm^2 Treatment Field Size

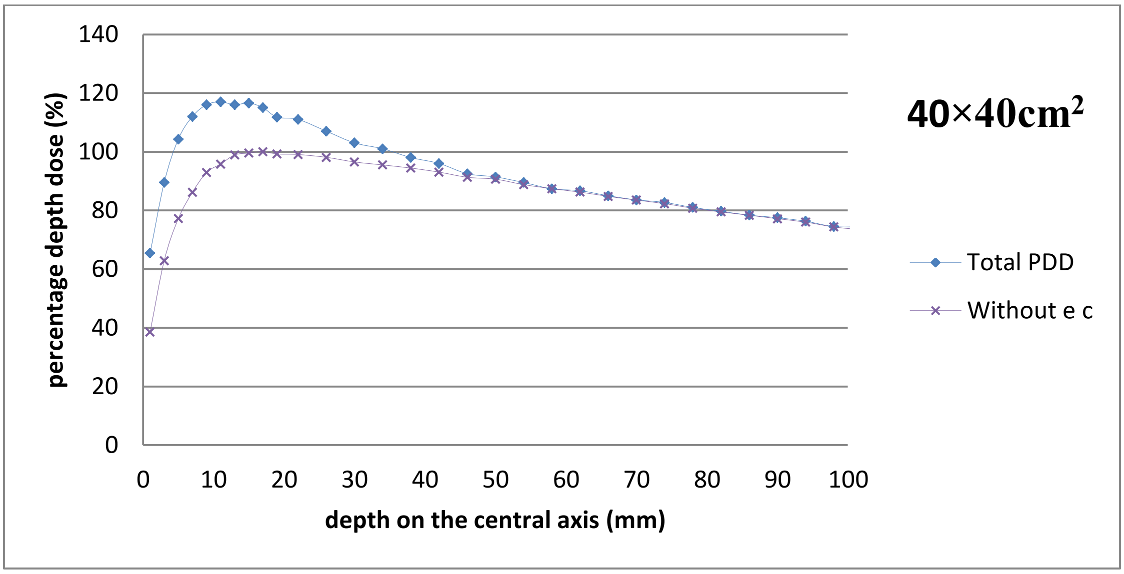

Figure 6: Total PDD and PDD without Electron Contamination for 40 × 40cm^2 Treatment Field Size

The electron contamination Percentage Depth Dose curves for 6MV photon beam as a function of field size (from 5×5 cm^2 to 40×40 cm^2) are presented in Figures 7 to 11, respectively.

Discussion

The results and findings of this research showed that the surface dose of electron contamination from linac head and air volume reduce the skin sparing advantages of Megavoltage beams. Studies on electron contamination sources in linacs have shown that for wide treatment fields, flattening filters and air below collimators are the main sources of electron contamination [6].

Research findings suggested that the incrementing of electron contamination surface dose is related to field size (6% for 5×5 cm^2 to 27% for 40×40 cm^2). The results are in agreement with other studies. Sheikh-Bagheri et al showed that the electron contamination contributes 0.35-1.37% to the maximum dose in the build-up region at 10MV and 0.26-3.29% of the maximum dose at 20MV [10]. Malataras et al reported that the contribution of the secondary contamination electrons on the surface dose is 16% for 6MV and 12MV, 6% for 15MV and 17% for 23MV [6]. The difference between results is due to a variety of materials that has been used in linac composition. The knowledge of the electron contamination characteristics is important in clinical dosimetry and it is different for each system and this calculating is necessary for all systems [5].

So, by increasing the surface dose, as a consequence of electron contamination and using bolus for a patient together, the skin of the patient will receive damages such as erythema, skin burning, desquamation and telangiectasia. Understanding the effect of electron contamination of photon beams is important for proper commission and test TPS calculation especially in build-up region. In either case it is vital to calculate electron contamination and measure build-up curves accurately in order to evaluate the accuracy of TPS calculation especially when bolus is used. Simultaneously, having definitive dosimetry at the surface and build-up region is important to optimize bolus thickness

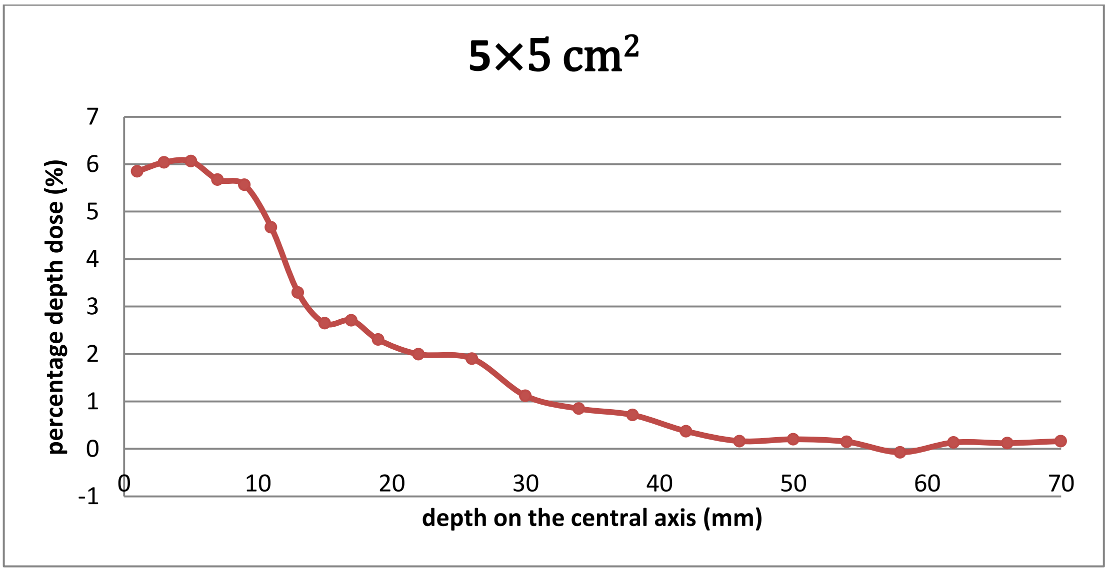

Figure 7: Electron Contamination PDD of 5×5 cm^2 Treatment Field

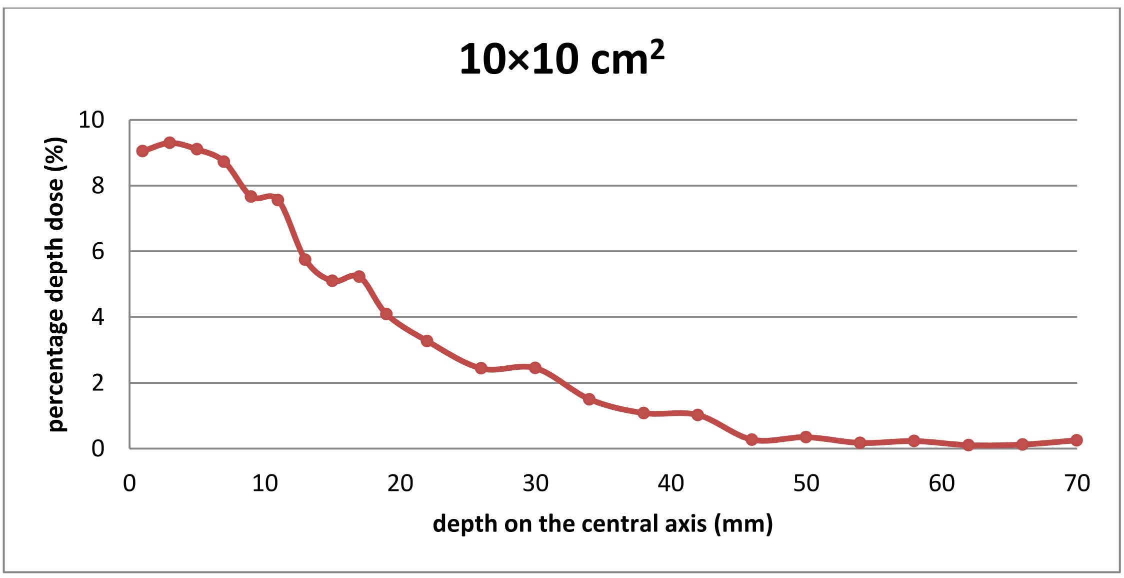

Figure 8: Electron Contamination PDD of 10×10 cm^2 Treatment Field

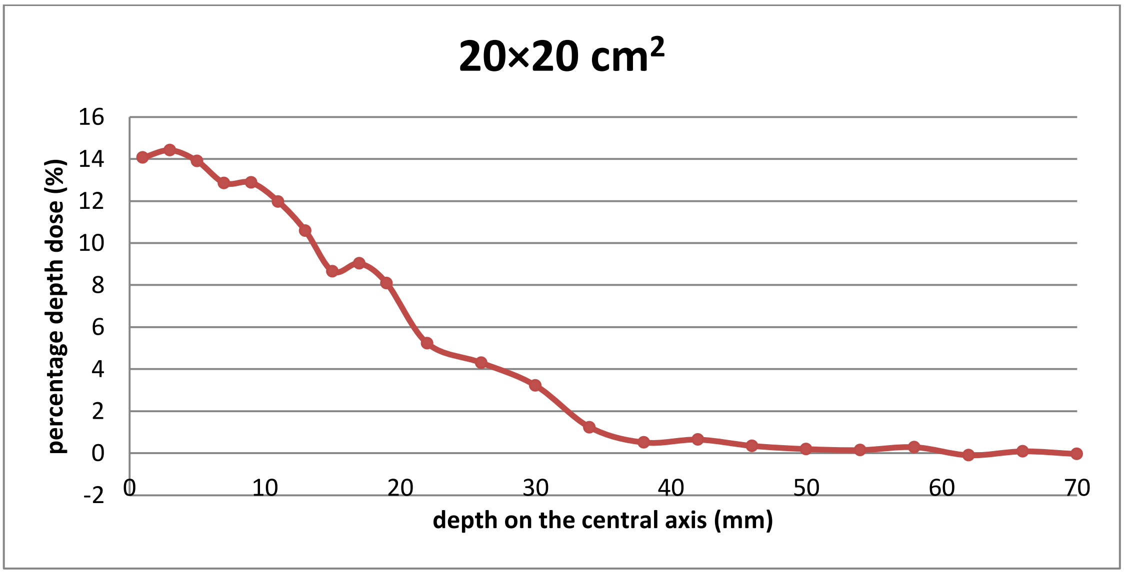

Figure 9: Electron Contamination PDD of 20×20 cm^2 Treatment Field

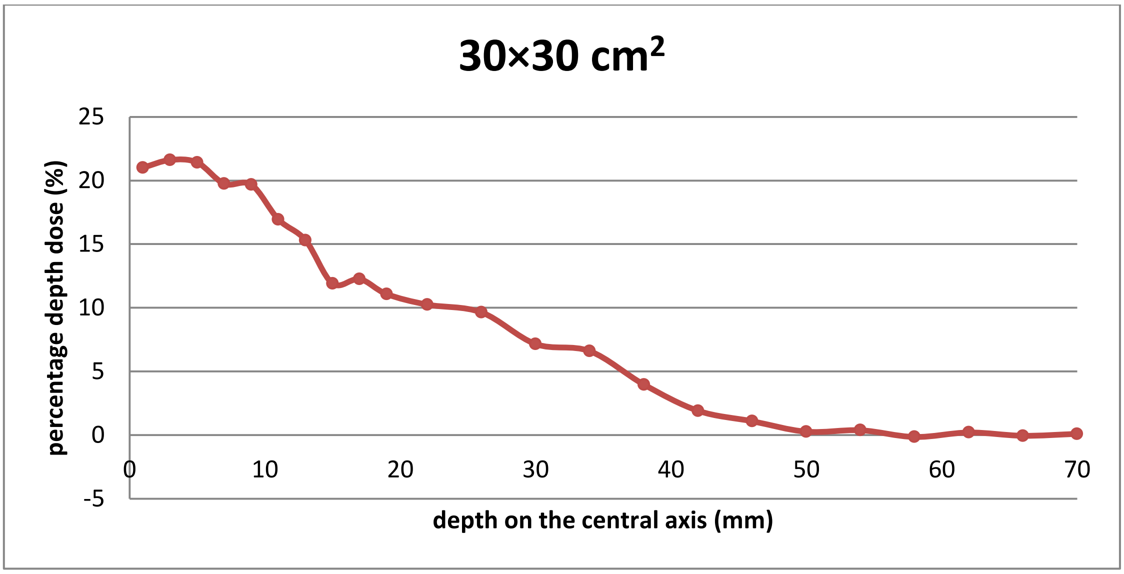

Figure 10: Electron Contamination PDD of 30×30 cm^2 Treatment Field

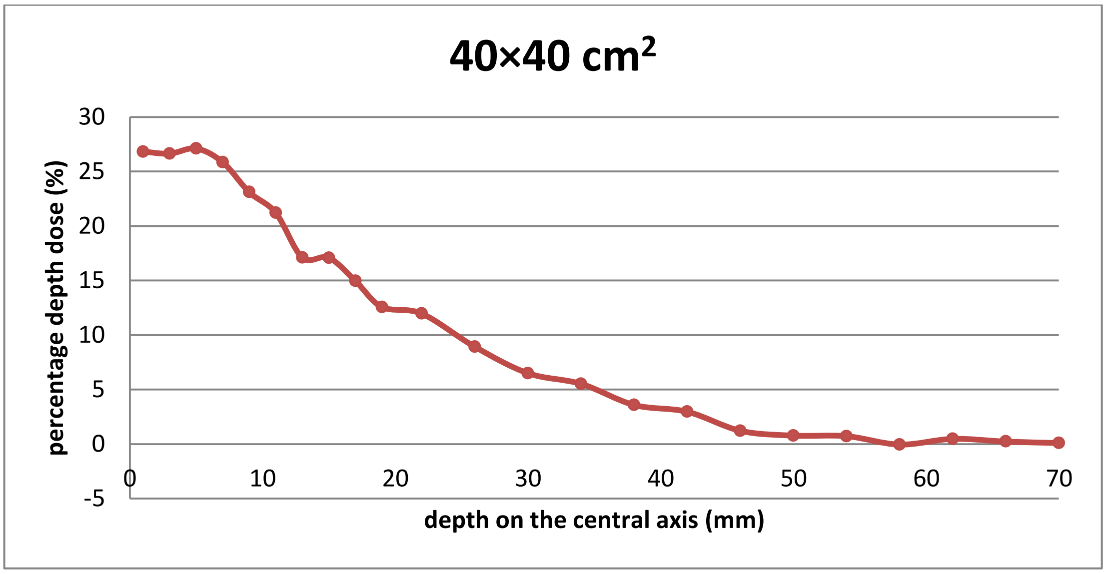

Figure 11: Electron Contamination PDD of 40×40 cm^2 Treatment Field

required to enhance surface dose in clinical cases such as inflammatory breast cancers in order to prevent patient's scorching.

The measured build-up curves can be utilized to optimize TPS calculations and guide bolus decisions.

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Conflict of Interest

None

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