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Dosimetric capabilities of the Iview GT portal imager using MCNP5 Monte Carlo simulations

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Abstract— **This work is focused on developing a methodology to obtain portal dosimetry with an amorphous silicon Electronic Portal Image Device (a-Si EPID) used in radiotherapy by means of Monte Carlo simulations and experimental measures. Pixel intensity values from portal images have been compared with dose measured from an ionization chamber and dose calculated from Monte Carlo simulations. To this end, several images were acquired with the Elekta iView GT EPID using an attenuator phantom slab (10 cm thickness of solid water) and a 6 MeV photon energy beam with different monitor units settings (MU). The average pixel value in a region of interest (ROI) centered at the beam for each image was extracted and compared to dose measures performed with an ionization chamber. These parameters were found to be linearly related with the number of monitor units. Since MCNP5 simulations allow calculating the deposited dose in the ROI within the phosphor layer of the EPID model, we could compare the portal dose with the simulated transit dose in order to perform a treatment control.**

I. Introduction

THE Electronic Portal Imaging Device (EPID) is a useful tool for medical physicists to verify the shape and the location of the therapy beam with respect to the patient's anatomy. Most EPIDs consist of a metal plate phosphor screen which transforms some of the MeV X-rays into optical light which is then directed by a combination of mirrors and lenses onto a camera and finally digitized. The portal image of the just finished session is compared with a reference image. This is done with a computer either interactively or by semiautomatic tools [1].

The fast development of these detection systems, which incorporate a semi-conductor matrix (amorphous silicon (a-Si) electronic portal imaging), has introduced the possibility of these systems becoming increasingly used for dosimetric verification of radiotherapy treatments, offering near-instantaneous 2D mapping of patient position and radiation profiles [2].

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In this work we propose the comparison of the simulated dose distribution obtained by Monte Carlo simulations, with experimental transit portal dose from the Elekta iView GT electronic portal imager. Measurements with an ionization chamber are necessary to establish a relation between the iView GT image gray level intensity and absorbed dose calculated by simulation, as simulation only gives selective values (per particle); and dose in linacs depends on the MU used during the irradiation.

II. Methods

An amorphous silicon flat panel Electronic Portal Imaging Device can be used not only for imaging but also for dosimetric applications in high energy photon beams. Physical characteristics and dosimetric capabilities of a commercially available a-Si EPID have been investigated.

For dosimetry, it is essential to study the EPID response, which involves the conversion from pixel intensity gray level to transit dose. The first part of the work is focused on this point, particularly we have investigated the dosimetric properties of the iView GT mounted on an Elekta Precise medical accelerator (Elekta Ltd, Crawley, UK).

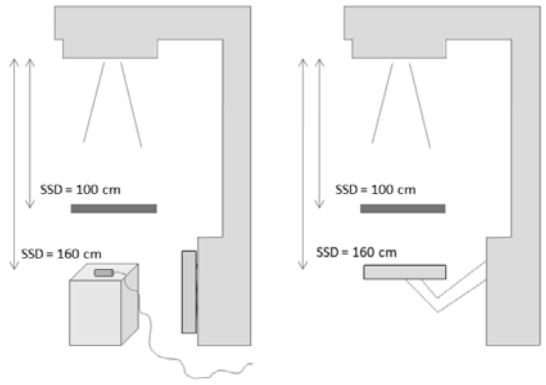
The second part of the work is focused in obtaining the absolute dose distribution at the level of the phosphor screen (Gd2O2S:Tb) by means of Monte Carlo simulation.

A. The experimental procedure

All experiments were performed with an Elekta Sli Precise linear accelerator provided by the Hospital Clínic Universitari de València, which has also provided all the facilities and personnel necessary to obtain experimental data.

All measurements were performed with a 6 MeV linear accelerator photon beam using the maximum available dose rate, i.e. 400 MU min^{-1}.

Two experimental procedures have been performed in this work. One of them involves measuring with an ionization chamber and the other one using the EPID with identical irradiation conditions. Both experimental set-up procedures diagrams are described in Figure 1 and detailed in the next sections.



(a) (b)

Fig. 1. Experimental set-up procedures.
(a) Measures taken with the chamber ionization
(b) Images taken with the EPID

B. Chamber ionization measures

Ionization chambers are considered the best way for dose measurements. In this study a cylindrical ionization chamber (a *Scanditronix-Wellhofer RK* thimble chamber) was used to derive the relationship between the EPID images and portal dose images. The ionization chamber was positioned below a solid water miniphantom slab with a transverse cross section of 20 cm x 20 cm and a thickness of 10 cm and positioned such as the half thickness corresponds to the isocentre position (100 cm from source).

The centre of the ionization chamber was positioned at a distance of 160 cm from the radiotherapy head focus, which is equal to the fixed focus-to-fluorescent screen distance of the EPID.

The block was irradiated with a 10 cm x 10 cm field size for the nominal energy of 6 MeV with monitor units (from 20 to 200 MU). Figure 2 shows the linear dependence between charge deposition at the ionization chamber and the number of monitor units (MU) used in each measure.

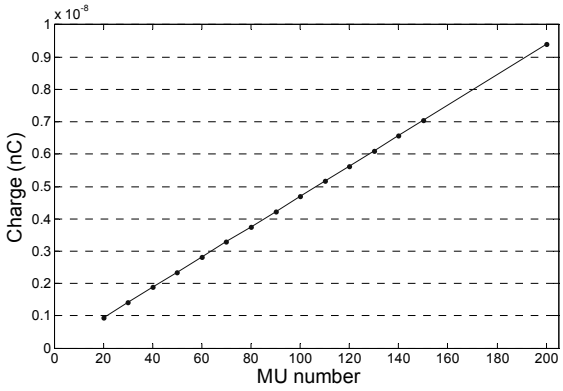


Fig. 2. Ionization chamber measurements placed at the iView level as a function of MU for a 10 cm x 10 cm field size.

C. EPID images

The *iView GT-type* EPID (Elekta) is based on the amorphous silicon detector panel XRD 1640 (Perkin-Elmer Optoelectronics, Fremont, CA) with a fixed source–detector distance (SDD) of 160 cm and a detection area of 41 cm x 41 cm [3], [4]. This system has a 1024x1024 pixel resolution and is composed first by a metal layer (copper + aluminum) as additional build-up material, in order to maximize deposited dose (i.e. obtaining the maximum image information) at the second layer constituted by the scintillator.

In a-Si EPIDs, the incoming X-rays are converted in a phosphor screen into light which is detected by an amorphous silicon photodiode array. Each pixel from the image corresponds to the association of a photodiode with a transistor, which transmits the current generated in the photodiode to the amplifier. This current is proportional to the light exposure corresponding to the pixels coordinates.

Portal images were acquired in the same irradiation conditions (isocentre at half thickness of the solid water phantom and 10 cm x 10 cm field size) using the commercial *iViewGT* software with a fixed integration time of 433 ms/frame.

All images were generated by integrating the frames acquired during the total radiation dose delivered. The number of frames integrated during beam delivery was estimated to range between 25 and 50, depending on the number of monitor units.

Images were exported from the acquisition console to raw format *.his* files and a correction filter map was applied to each image sequence, in order to eliminate the offset noise, to apply a link offset correction (bad pixels correction) and to perform a heterogeneity detector correction.

Exposure is related with the image grey level intensity. This relation is translated in a curve, as can be seen in Figure 3, called the sensiometric curve, which is characteristic for each film, and expresses the optical density as a function of received dose.

The average pixel value was extracted from a region of interest of 15x15 pixels (ROI) along the central axis of the beam.

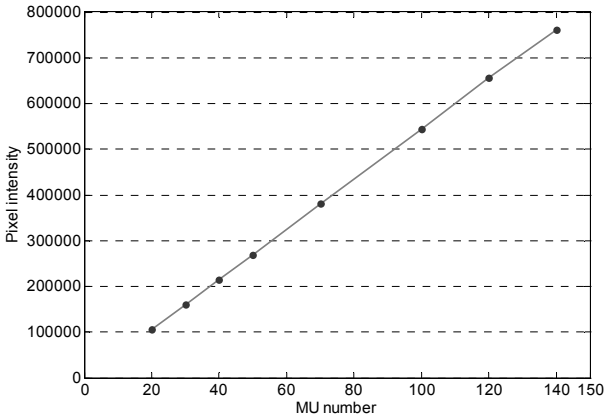


Fig. 3. Grey levels as a function of MU for a 10 cm x 10 cm field size.

III. RESULTS

A. Dosimetric capabilities of electronic portal imager: Evaluation

EPID dosimetric characteristics have been analyzed demonstrating, in the presence of an attenuation material placed in the beam (a solid water slab), the linear relation between deposited dose at the imager and the pixel gray-scale intensity of the resultant image.

As presented in Figure 4, dose (measured by ionization chamber) in units of deposited charge (nC) and pixel values were found to be linearly associated with the number of MU.

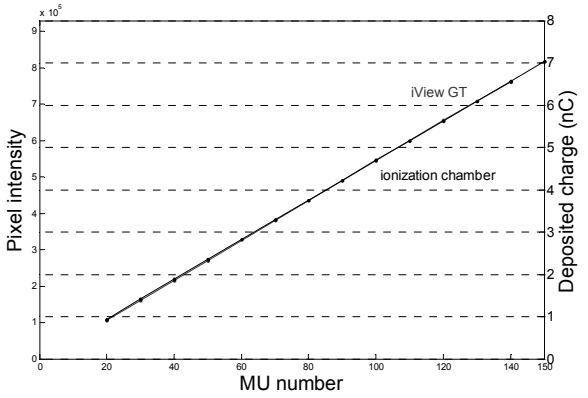


Fig. 4. Association of pixel value-to-MU for studied field size (10 cm x 10 cm) and a phantom thickness equal to 10 cm.

With reference to the ionization chamber measurements, the calibration factor to obtain absorbed dose to water from charge with the ionization chamber, for a 6 MeV photon beam at a temperature of 20ºC and a pressure of 1013 hPa is ND,w=4.761 cGy/nC. Hence therefore, deposited dose can be related with the ROI gray level intensity as Figure 5 shows.

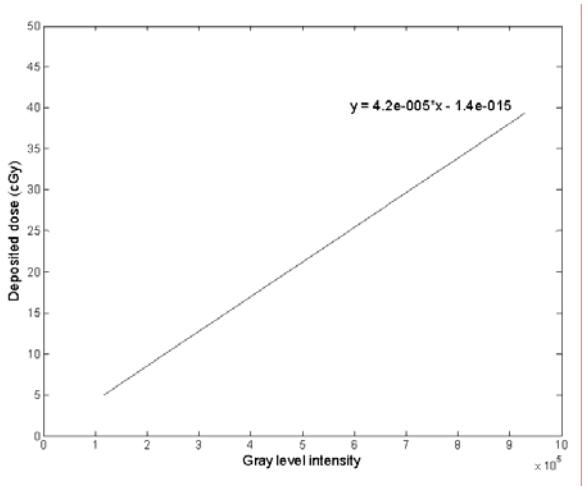


Figure 5. Association of pixel value-to-deposited dose for studied field size (10 cm x 10 cm).

B. Computing transit dose: Monte Carlo Simulations

The second part of the work is based on a Monte Carlo (MC) simulation of the EPID to obtain portal images and to compute the transit dose [5].

To this end, the detailed geometry of the radiotherapy treatment head unit *Elekta Precise* (see Figure 6), [6], the solid water phantom and the EPID amorphous silicon flat-panel (see Figure 7) have been accurately implemented in the Monte Carlo model according to the manufacturer data.

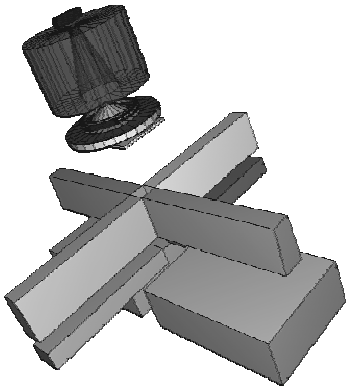


Fig. 6. Schematic diagram of the Elekta Precise accelerator head unit used for the Monte Carlo model.

We have used the electron and photon transport code MCNP5 from *Los Alamos National Laboratory* [7] for simulating the interaction of X-rays in the MeV energy range with the metal plate phosphor screen.

Incident X-rays can either interact with the metal plate or the phosphor screen. The dominant interaction processes (if the energy of the incoming X-ray is larger than 1.022 MeV) are either Compton scattering or Pair production, (creating an electron–positron pair which is highly forward directed). In the latter case, electrons and positrons begin to travel and gradually lose their kinetic energy by ionizing their environment until they are stopped (electrons), undergo recombination (positrons) or exit the detector. Positrons which recombine with electrons produce two γ-photons which can undergo further interactions or escape.

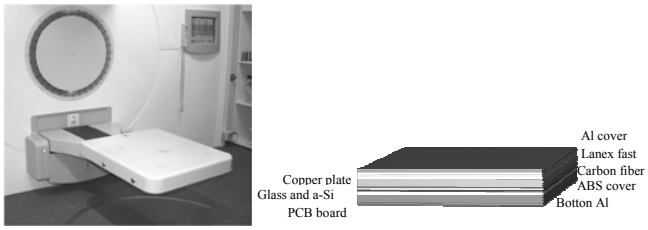


Fig. 7. Schematic diagram of the electronic portal imaging device used for the Monte Carlo model.

The X-ray energy spectrum used was obtained after 6 MeV monoenergetic electrons collided with a tungsten target located at the target block.

The MCNP5 code allows accurate registration of the relative flux and dose deposition (using the corresponding flux-to-dose conversion factors) at the flat-panel light phosphor layer by means of a new feature available in version 5, the FMESH tally.

The pixel resolution of the Monte Carlo EPID model was set to 0.4 cm x 0.4 cm (as the fixed screen panel resolution) to allow adequate spatial sampling in dose calculation.

The response of the imager in the sensitive layer of the detector was simulated in the same irradiation conditions as the experimental procedure was done.

Previous works validated the Monte Carlo simulation comparing relative depth dose and profile curves inside a water phantom [6].

The relative dose obtained by simulation at a ROI placed in the center beam axis can be related with the absolute dose at different MU to obtain a conversion factor coefficient curve in order to convert results from the FMESH tally to pixel intensity at the EPID images (Figure 8).

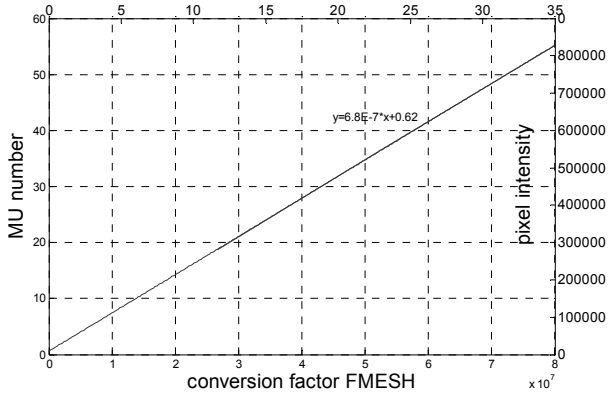


Fig. 8. Conversion factor to convert results from FMESH tally to pixel intensity.

The results presented in Fig. 8 allow comparisons of the portal transit dose with the simulated relative dose (grey level intensity). Moreover, these results allow comparison of doses calculated by simulation, with pixel intensities obtained.

IV. Discussion

With the increasing number of facilities using EPIDs for radiotherapy treatment, interest in calculating accurate EPID dose distributions is growing. A solution for this problem is the use of Monte Carlo methods.

The objectives of this study were firstly to simulate the iView GT amorphous silicon operation and secondly, to analyze the differences between simulation results and measurements.

The dosimetric abilities of the iView GT and the good agreement between the simulations and the experiments allow comparison of the portal transit dose in external beam radiotherapy accelerators with the simulated dose, in order to perform dosimetric quality control checks and to verify treatments (*in vivo* dosimetry).

Acknowledgment

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