

An improved Monte-Carlo model of the Varian EPID separating support arm and rear-housing backscatter

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Abstract. Previous investigators of EPID dosimetric properties have ascribed the backscatter, that contaminates dosimetric EPID images, to its supporting arm. Accordingly, Monte-Carlo (MC) EPID models have approximated the backscatter signal from the layers under the detector and the robotic support arm using either uniform or non-uniform solid water slabs, or through convolutions with back-scatter kernels. The aim of this work is to improve the existent MC models by measuring and modelling the separate backscatter contributions of the robotic arm and the rear plastic housing of the EPID. The EPID plastic housing is non-uniform with a 11.9 cm wide indented section that runs across the cross-plane direction in the superior half of the EPID which is 1.75 cm closer to the EPID sensitive layer than the rest of the housing. The thickness of the plastic housing is 0.5 cm. Experiments were performed with and without the housing present by removing all components of the EPID from the housing. The robotic support arm was not present for these measurements. A MC model of the linear accelerator and the EPID was modified to include the rear-housing indentation and results compared to the measurement. The rear housing was found to contribute a maximum of 3% additional signal. The rear housing contribution to the image is non-uniform in the in-plane direction with 2% asymmetry across the central 20 cm of an image irradiating the entire detector. The MC model was able to reproduce this non-uniform contribution. The EPID rear housing contributes a non-uniform backscatter component to the EPID image, which has not been previously characterized. This has been incorporated into an improved MC model of the EPID.

1. Introduction

Dosimetry with electronic portal imaging devices (EPIDs) can provide a highly efficient means to perform pre-treatment quality assurance for complex delivery techniques, as well as transit-type dosimetry for patient dose verification [1, 2]. For the Varian EPID system the backscatter from the EPID supporting arm, cables, and layers underneath the sensitive Gd_2O_2S layer contributes additional non-uniform signal to the dose image. This has been quantified as up to 7% additional signal for a flood-field irradiation of the EPID [3, 4]. It therefore affects the reliability of the EPID as a dosimetry device [1, 2]. Currently there are several different methods for quantifying, modelling, and removing the backscatter from the EPID supporting arm when performing EPID dosimetry. Some authors have regarded the backscatter material as uniform in composition. Rowshanfarzad et al. [5] developed an analytical model of back-scatter with a backscatter kernel derived from the results of pencil-beam backscatter measurements acquired with the EPID on and off the support arm. Siebers et al. [6] developed a comprehensive MC model of the EPID and established that a uniform water slab, added



underneath the EPID original layers was necessary to account for the field-size dependence of EPID signal at central axis. Wang et al. [7] extended this method by determining specific water-equivalent thicknesses to account for different field size response of imagers. Other authors have regarded the backscatter material as non-uniform. Cuffin et al. [8] added water-equivalent slabs of non-uniform thickness at the bottom of the original EPID layers for their MC model of extended fields. To improve MC modeling of EPIDs we have applied a novel approach of optimizing the MC model using EPID data recorded without the support arm present. This decouples the arm backscatter artifact from the EPID model and enables model parameters and model components for EPID dose deposition and arm backscatter to be independently optimized. As with previous studies we initially modeled the rear plastic housing of the EPID as a uniform layer of plastic. However comparison of the measured and the predicted doses resulted in some disagreement, particularly in the low dose region. This suggested that some contributions of backscatter were still present in the measurements. An indentation in the EPID rear housing layer was therefore investigated. In this paper we experimentally measure the effect of the rear housing with this indentation on EPID signal and we incorporate the indentation into our MC model for comparison to measurements. The results shed new light on the sources and effects of EPID backscatter and how to effectively model EPIDs using Monte-Carlo for dosimetric applications.

2. Materials and Methods

The EPID used in this study was the Varian IDU20 aS500 model (Varian Medical Systems, Palo Alto, CA, USA). The EPID was no longer used due to damage to some rows at the top and bottom of the EPID that are not able to contribute signal. This restricted the signal that was obtained in the in-plane direction from 10.04 cm below the central axis to 10.03 cm above the central axis on the EPID. The bottom housing is non-uniform with an 11.9 cm width and 1.75 cm depth indented section running in the cross-plane direction in the upper half of the EPID (Figure 1). The indented section is 1.75 cm closer to the EPID sensitive layer than the rest of the housing. The thickness of the plastic housing is approximately 0.5 cm in all directions (determined from CT scan of the EPID) including the indentation walls.



Figure 1. EPID viewed from underneath showing the indentation in the rear housing

In order to quantify the contribution of the rear housing to the measured dose, the EPID was positioned on a low density styrofoam plate on the linac couch. The EPID was connected to a separate digitization unit and acquisition computer used for research. Images for jaw-defined open fields of sizes 5×5 , 10×10 , 20×20 cm² and an image covering the entire detector were acquired with 6 MV energy on a Varian Trilogy linac at 105 cm to the EPID sensitive layer. The EPID layers and electronics were then removed from the EPID housing and repositioned on the styrofoam and the measurements repeated. Images were acquired without any corrections applied to the images to examine the raw EPID signals. To compare to the MC model a separate measurement was performed with the same model of EPID but in clinical use. This EPID was removed from the support arm and supported at the sides without a treatment couch underneath. Measurements with a 20×20 cm² field

were obtained again with raw EPID signal. The BEAMnrc MC code [9] was used to simulate photon and electron propagation from the target through the linac head for 6 MeV photons down to the phase space plane which is defined at the linac isocenter. The energy of the incident electron beam was 6.02 MeV with a FWHM of 0.12 cm. The linear accelerator The DOSXYZnrc MC code [10] was used to simulate propagation of particles from the phase space down through the air gap and the α -Si EPID modeled as $40 \times 30 \text{ cm}^2$ layers with 0.1 cm pixel resolution. The center of the EPID sensitive layer was positioned at 105 cm from the target for consistency with the experimental set-up. The surrounding medium was defined to be uniform air. The MC EPID model comprised 22 layers, as described in the manufacturer's specification data sheets and in Siebers et al. They included the Cu buildup plate, the $\text{Gd}_2\text{O}_2\text{S}$ phosphor screen, the detector front cover and the rear housing. The standard EPID model, which comprises uniform homogeneous slabs, was modified to accommodate the rear-housing indentation. The first 19 layers were modeled as a sequence of uniform material slabs. The last 3 layers were partially filled with the back-housing cover and partially with air therefore reproducing the indentation at the bottom. The model results for a $20 \times 20 \text{ cm}^2$ field were compared to raw EPID data measures with the EPID removed from the support arm as described above.

3. Results

An in-plane profile through the central axis of the ratio of the entire detector image recorded with and without the rear housing present is shown in Figure 2. The maximum additional backscatter signal contribution of the housing is approximately 3% and is 2.5% at central axis. Furthermore, the contribution is non-uniform in the in-plane direction with about 2% asymmetry across the central 20 cm of the field irradiating the entire detector. The backscatter contribution from the support arm for a field irradiating the entire detector has been previously quantified from measurements on and off the arm. This contribution does not include rear housing backscatter as this is present in both on and off arm measurements and therefore cancels. The separate backscatter from the rear housing has been determined in this work.

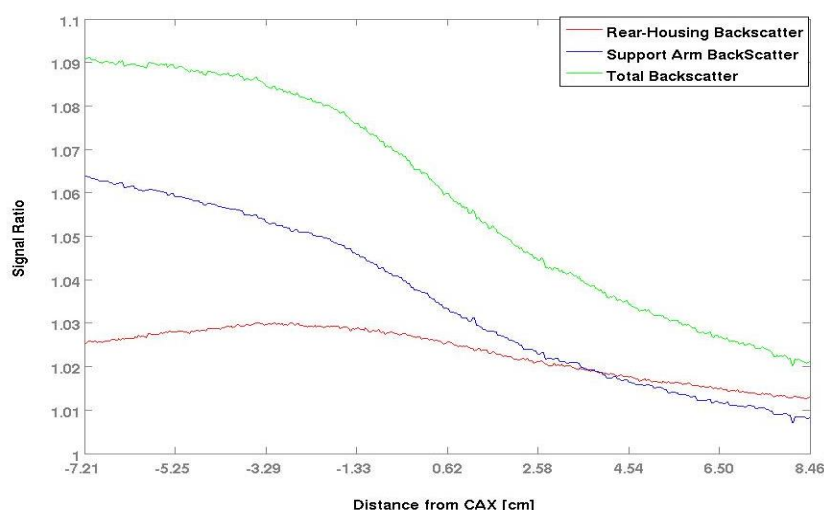


Figure 2. EPID rear housing backscatter. A profile in the in-plane direction of the ratio of EPID signal with and without housing present is plotted. Also plotted for comparison is the support arm backscatter along with the total backscatter from these sources.

In Figure 2, the two separate backscatter components (ratio of with and without backscatter) are shown using in-plane profiles along with the total backscatter contribution (housing + support arm) to the EPID signal. This is a maximum of 9% with a gradient of over 6% across the in-plane distance. Profiles for a $20 \times 20 \text{ cm}^2$ field are shown in Figure 3. The effect of the rear housing is insignificant for smaller fields, showing that the area of irradiation of the housing is important. The MC code is able to reproduce the non-uniform contribution of the indented rear-housing to the measured dose in the in-plane direction as shown in Figure 4 where the raw measured dose is compared against the predicted. In spite of modeling the effect of the indentation on

the measured signal, some disagreement is still noticeable over the tails of the profiles in the in-plane direction. The EPID housing case study was finalized by analyzing also the relative response or field size factor at central axis for the open fields normalized to the $10 \times 10 \text{ cm}^2$ field. The MC model agreed with the measured factors to within 0.5%.

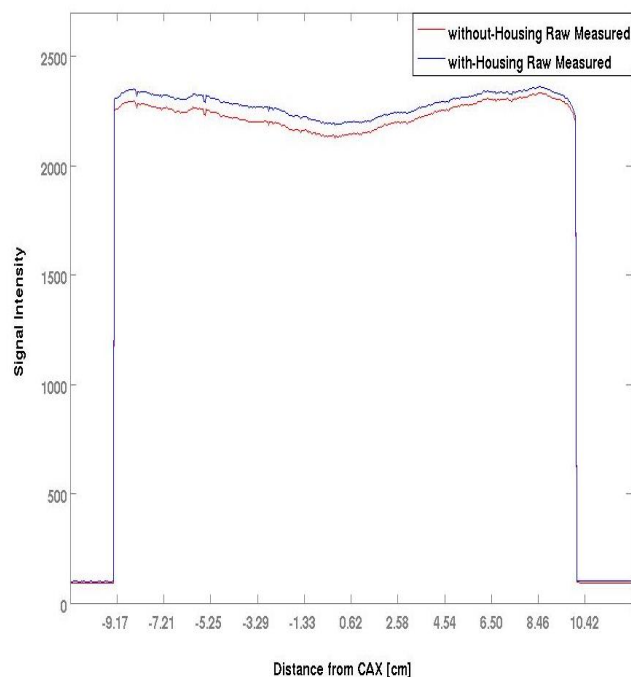


Figure 3. Open-field EPID profiles with and without the rear-housing present for a $20 \times 20 \text{ cm}^2$ field. The raw EPID in-plane direction through central axis is plotted in each case

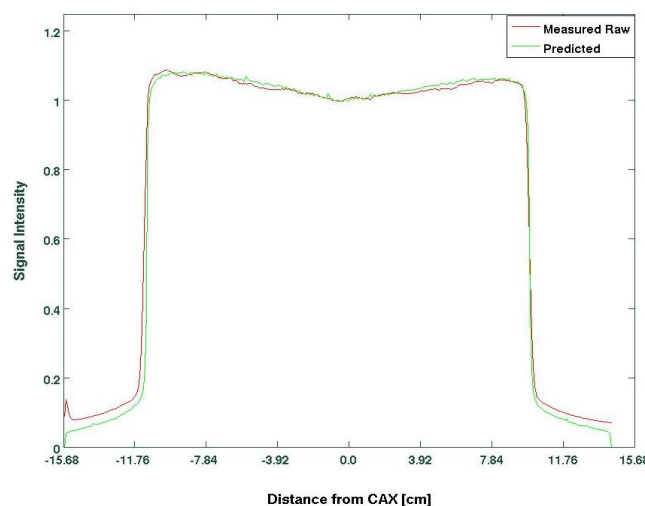


Figure 4. Comparison of MC model with the indented rear-housing and measured raw image. The normalized profile in the in-plane direction through central axis for a $20 \times 20 \text{ cm}^2$ field is plotted.

4. Discussion

Some details of the EPID are not present in the model including screws, nuts, and metallic parts that are also sources of backscatter. These could contribute to some of discrepancies in the low dose tails observed in Figure 4. The source of these discrepancies is not known but are believed to be backscatter related. Indirect evidence of this was obtained by comparing MC model to measurement for a backscatter shielded EPID model where a layer of lead shields the sensitive layer from backscatter radiation contamination [11]. This comparison did not produce a measured tail region higher than the

predicted. The results here are in broad agreement with the findings of Schach von Wittenau et al. [12] who concluded that radiation scattered from non-detector components of the detector itself, such as the front and back covers, are significant sources of image blurring. When an image acquired with the entire EPID irradiated is flood-field or pixel sensitivity matrix corrected, the backscatter from the rear housing (and support arm) is not apparent as the same backscatter is present in both the acquired and the correction image and hence cancels. However when the field size changes, there will be a mismatch in the scatter in both images and backscatter artifacts become apparent. It is clear from this work that previous methods to account for this backscatter artifact are in fact simultaneously modeling or correcting both support arm and rear housing non-uniform backscatter artifacts. The next stage of this work will be to model the support arm backscatter contribution to the EPID.

5. Conclusion

The EPID rear plastic housing contributes a non-uniform backscatter component to the measured dose which has been characterized here using measurements with the EPID layers removed from the housing. This additional source of dosimetric image contamination has been incorporated into an improved Monte Carlo model of the Varian EPID.

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