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A self-sufficient method for calibration of Varian electronic portal imaging device

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A self-sufficient method for calibration of Varian electronic portal imaging device

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Abstract. Electronic portal imaging device (EPID) is currently used for dosimetric verification of IMRT fields and linac quality assurance (QA). It is critical to understand the dosimetric response and perform an accurate and robust calibration of EPID. We present the implementation of an efficient method for the calibration and the validation of a Varian EPID, which relies only on data collected with that specific device. The calibration method is based on images obtained with five shifts of EPID panel. With this method, the relative gain (sensitivity) of each element of a detector matrix is calculated and applied on top of the calibration determined with the flood-field procedure. The calibration procedure was verified using a physical wedge inserted in the beam line and the corrected profile shows consistent results with the measurements using a calibrated 2D array. This method does not rely on the beam profile used in the flood-field calibration process, which allows EPID calibration in 10 minutes with no additional equipment compared to at least 2 hours to obtain beam profile and scanning beam equipment requirement with the conventional method.

1. Introduction

Electronic portal imaging device (EPID) was initially developed for patient positioning, verification, and it is recently being utilized for dosimetric verification of IMRT treatments and linac quality assurance (QA), including dose output, beam profile, field size, MLC, wedge factor, etc. The EPID-based QA offers many advantages over the conventional methods: high spatial resolution, fast image acquisition, and digital output allowing a fast quantitative analysis. It provides an efficient and accurate tool for both patient and machine QA in radiation therapy [1].

Conventional methods for calibration of EPID includes dark-field and flood-field irradiations at a fixed panel position and requires a beam profile correction for off-axis ratio differences, which is typically collected with a scanning water tank. It is expected that some variations in detector's sensitivities are inevitable. Many different calibration techniques have been developed to compensate the variations. One of the methods to determine the relative gain of each detector element relies on comparison of the detector response when irradiated by the same fluence. By shifting or rotating the detectors, the gain of each detector relative to the central axis can be obtained. The general idea has been applied to calibrate various 2D array detectors including EPID [2-4]. Recently, Boriano *et al* [5] applied this approach to EPID calibration of Elekta iViewGT. In this paper we describe a self-sufficient procedure, related algorithm, results and verification for the calibration of Varian EPID devices.

2. Materials and Methods

A Varian Truebeam linear accelerator (Varian Medical Systems, Palo Alto, CA) equipped with amorphous silicon panel (*a*Si1000) was used in this study. The EPID has a resolution of 1024 x 768 pixels with a 40 x 30 cm^2 active detector area. The pixel size projected back to isocenter is 0.392 mm. All the irradiations were performed with a 6 MV beam of 100 Monitor Units (MUs). The standard calibration following manufacture's guideline was performed in service mode: i) An image of a dark-field was acquired while the beam was off; ii) A flood-field calibration was performed with an open beam covering the whole active detector area. This eliminates variation in sensitivity between different detector elements and areas of the panel; iii) A generic beam profile for off-axis correction provided by Varian was applied for the flood-field calibration.

The EPID was positioned at 108 cm source to detector distance (SDD) and the gantry was set at 0 (IEC scale). EPID images were acquired in integrated mode through Mosaiq (Elekta Medical Systems, Sunnyvale, CA) and saved in DICOM format. Data analysis and algorithm development were carried out using Matlab programming language (The Mathworks INC., Natick, MA). The calibration procedure consists of five consecutive deliveries with the same fluence. Each delivery was performed at the same SDD with an open field size of 22 x 22 cm^2. The first image was acquired when the EPID was in the central position with respect to the beam. The other four images were acquired with the EPID shifted along left, right, towards and away in the gantry table directions. Each shift was approximately 4 mm (10 pixels). Two different coordinate systems were defined in the algorithm: One, (x,y) is associated with the accelerator and the other, (i,j), is linked with the EPID system. During the five acquisitions of the calibration procedure, the center of the EPID has been placed respectively at the following coordinates (x, y): (0, 0), (0, 10), (0,-10), (10, 0), and (-10, 0). The fluence F (i, j), EPID readout I (i, j) and gain G (i, j) are related by equation where M is the maximum pixel number determined by the field size.

$$I(i,j) = F(i,j) \times G(i,j) \qquad (1)$$

When the EPID was at the central position, The EPID readout was given by

$$I_C(i,j) = F_C(i,j) \times G(i,j) \qquad (2)$$

When the EPID was made to right shift by 10 pixels, the EPID readout was expressed by

$$I_R(i+10,j) = F_R(i+10,j) \times G(i+10,j) \qquad (3)$$

It is assumed that the fluence does not change during the subsequent deliveries:

$$F_C(i,j) = F_R(i+10,j) \qquad (4)$$

By applying Eq.4 to Eq 2 and 3, one obtains

$$G(i+10,j) = \frac{I_R(i+10,j)}{I_C(i,j)} \times G(i,j) \qquad \text{for } i = (1,\ 2,\ 3,\dots,\ \mathrm{M}) \qquad (5)$$

By repeating the same analysis, the gain for each detector element, as a 2D sensitivity map, can be related to the gain of the central region as a reference. In our study the reference region is G (i, j) = 1 for i = -10, -9, ..., 10 and j = -10, -9, ..., 10. The procedure and algorithm was verified using a physical wedge inserted in the beam line during flood-field irradiation. Therefore, a non-uniform beam was used for flood-field calibration and a wedged profile was expected without applying the 2D sensitivity map for an open field delivery. The 2D sensitive map was calculated and applied to a non-uniformed beam acquired with an open field.

3. Results

Figure 1(a) shows an image acquired using a 6 MV beam open field of a 22x22 cm^2. The central circle shows a flattering filter, which was not present in the image of a flattering-filter free beam [6]. After making 4 shifts of the EPID panel, the pixel sensitivity map was calculated as shown in figure 1(b). The variation of detector response ranges from 0.93 - 1.06.

Figure 1(c) shows the corrected image after applying the 2D sensitivity map. The horn effect was less pronounced and the image was more uniform.

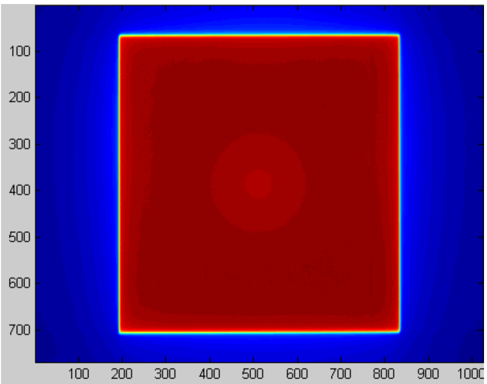

Figure 1(a). Open field images without sensitivity correction.

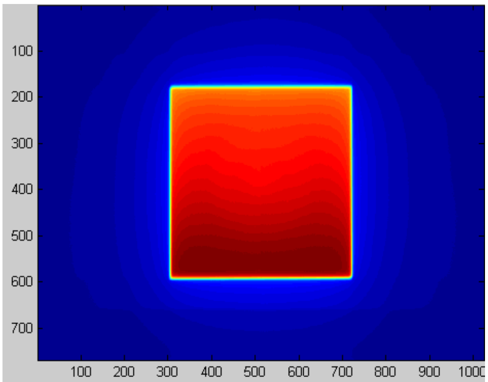

Figure 2(a). Open field images acquired with the flood-field calibrated when a 15 degree physical wedge in the beam line.

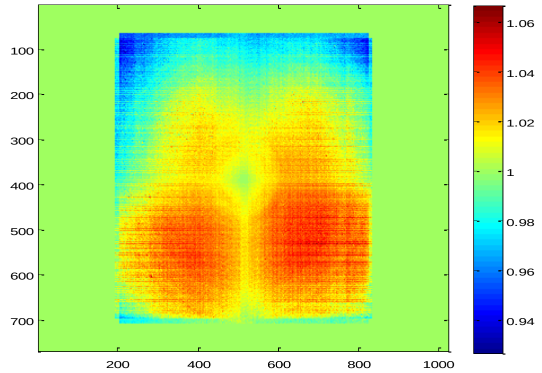

Figure 1(b). Calculated 2D sensitivity map.

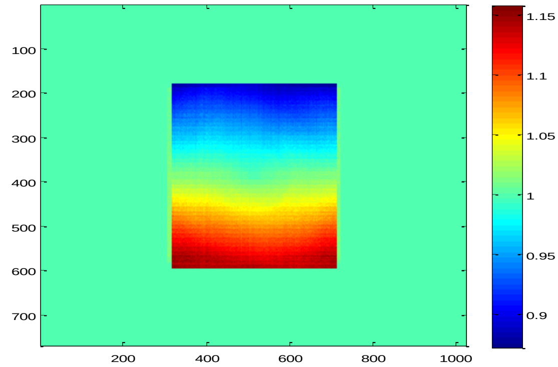

Figure 2(b). Calculated 2D sensitivity map for intentionally modified flooding field calibration.

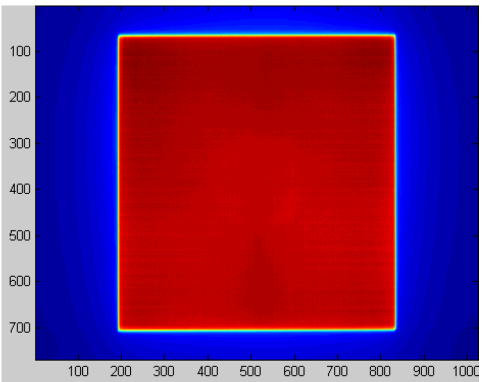

Figure 1(c). Open field images with sensitivity correction.

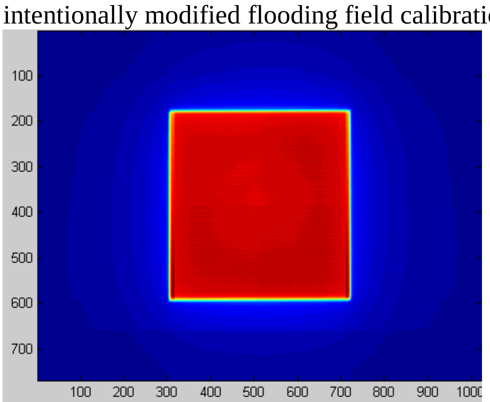

Figure 2(c). EPID image after applying the calculated 2D sensitivity map in figure 2(b).

Figure 2 shows the results of the verification described above. Figure 2(a) shows the image of a 15 x 15 cm^2 open field after intentionally introduced a wedge during the flood-field calibration. The beam profile presents a wedge beam along the gantry-table direction. Figure 2(b) is the calculated sensitivity map for the verification setup. Figure 2(c) shows the corrected EPID image after applying the calculated gain for each pixel. The coordinates of both x- and y-axes are shown as pixel positions. Figure 3(a) and (b) shows the beam profile in the central axis along the gantry-table direction, before and after the correction of the 2D sensitivity map, respectively. The corrected EPID image and beam profile using our calibration procedure has indicated that the new calibration procedure is independent of the beam profile used in the flood-field irradiation. The corrected beam profile was compared with measurements at D_{max} using a different 2D detector array (Matrixx, IBA Dosimetry GmbH, Germany) and the profile flatness and symmetry were in an agreement within 0.5%.

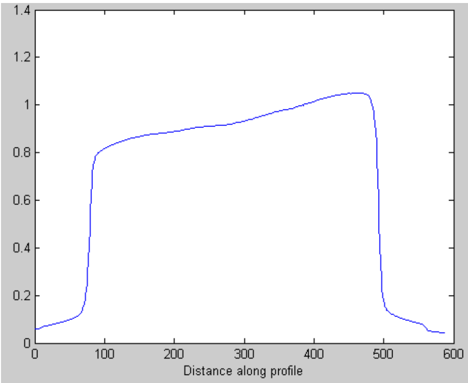

Figure 3(a). Wedged profile without correction of sensitivity map.

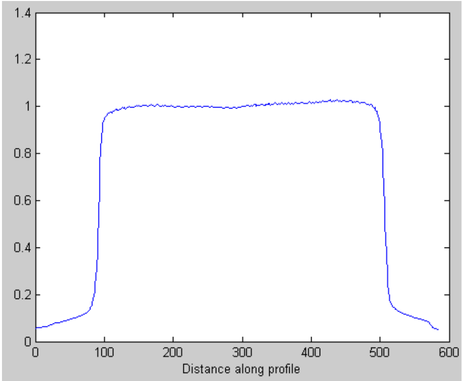

Figure 3(b). Beam profile after the correction.

4. Conclusion
We have developed a self-sufficient procedure and algorithm for calibration of a Varian EPID. This method is easy and fast to implement. It requires only a sequence of five measurements which are then processed with a simple algorithm. This method does not depend on the beam profile required in the flood-field irradiation and is more robust compared to the standard calibration methods recommended by the manufacture's guide. The verification presented in this paper has shown the goodness of the procedure and algorithm.

5. References
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