Clinical validation of an in-house EPID dosimetry system for IMRT QA at the Prince of Wales Hospital

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Abstract. In this study a simple method using standard flood-field corrected Electronic Portal Imaging Device (EPID) images for routine Intensity Modulated Radiation Therapy (IMRT) Quality Assurance (QA) was investigated. The EPID QA system was designed and tested on a Siemens Oncor Impression linear accelerator with an OptiVue 1000ST EPID panel (Siemens Medical Solutions USA, Inc, USA) and an Elekta Axesse linear accelerator with an iViewGT EPID (Elekta AB, Sweden) for 6 and 10 MV IMRT fields with Step-and-Shoot and dynamic-MLC delivery. Two different planning systems were used for patient IMRT field generation for comparison with the measured EPID fluences. All measured IMRT plans had >95% agreement to the planning fluences (using 3 cGy / 3 mm Gamma Criteria) and were comparable to the pass-rates calculated using a 2-D diode array dosimeter.

1. Introduction
Intensity Modulated Radiation Therapy (IMRT) is used routinely for prostate, head and neck, and abdominal treatment sites at the Prince of Wales Hospital (POWH). Per-patient pre-treatment QA on treatment fields is recommended in ESTRO Booklet 9 [1], ICRU Report 83 [2] and the ASTRO practice guideline for IMRT [3]. All IMRT treatments at the POWH have QA performed with the MapCHECK (Sun Nuclear Corporation, Fl, USA) two-dimensional diode array dosimeter for a per-field comparison with treatment planning system (TPS) planar dose fluences. The comparison method used is Gamma Analysis with 3 cGy / 3 mm criteria, with greater than 95% of the dose points being in the criteria. Ongoing increases in IMRT patient workload puts pressure on physics resources and has led to investigations for alternatives to the standard diode array based method.

Amorphous silicon (a-Si) Electronic Portal Imaging Devices (EPIDs) have been implemented for two-dimensional dosimetry in many departments globally. EPIDs have many characteristics that make them well suited for IMRT dosimetry [4-8] and the reduced equipment set-up time compared to other dosimeters has the potential to improve efficiencies. Many approaches have been implemented for portal dosimetry as described in a review paper by Van Elmpt [9]. Despite numerous research papers on the topic, and several commercial products being available, portal dosimetry is not yet widespread across all vendor equipment.
Lee [10] implemented a simplified model for Varian EPID dosimetry that calculated a reference depth in water ($d_{ref}$) at which the EPID response matched conventional dosimeters. The EPID dose response was matched to dose in water at $d_{ref}$ based on field size factors and profile shape. This method eliminates the need for complex scatter corrections and EPID modeling and makes use of an existing TPS to predict EPID response, providing a simple QA tool for IMRT available to any department. This method has not yet been implemented on non-Varian equipment. In this work we implement a similar model across a variety of planning and delivery platforms available at POWH.

2. Materials and Methods

2.1. EPID image acquisition

EPID images were acquired using non-transit methods (no object in the path of the beam), with the panel set at an SSD of 145 cm for the Siemens OptiVue1000ST and 160 cm for the Elekta iViewGT. Based on preliminary measurements a 1 cm solid-water plate was required on the EPID panel for 10 MV measurements to allow sufficient build-up for electronic equilibrium in the detector. No build-up was required for 6 MV measurements.

Images were exported as frame-averaged images in DICOM format for the Siemens OptiVue1000ST, and lossless JPEG format for the Elekta iViewGT. Image analysis software was used for conversion of frame-averaged images to integrated images and for analysis of measured EPID fields.

2.2. EPID Calibration

Methods for determining the reference depth in water ($d_{ref}$) were adapted from the work by Lee [11] for Siemens and Elekta EPID images. One difference in the method we used to that of Lee et al. is that we did not implement a profile correction. In our method the FF corrected images were used as acquired. Details of determining $d_{ref}$ will be reported elsewhere.

Pixel values for a measured field must be converted to absorbed dose using a measured pixel-to-dose calibration factor ($CF_{EPID:Dose}(x,y)$) for EPID dosimetry. The calibration factor was calculated for 6 and 10 MV based on measurements with the EPID and the absorbed dose in water at $d_{ref}$ for a 10 x 10 cm$^2$ field. The $CF_{EPID:Dose}(x,y)$ was calculated by dividing the absorbed dose at $d_{ref}$ ($Dose_{dref}$) by the average EPID pixel value (in a 0.4 x 0.4 cm region) at the beam central axis ($Pixel(x,y)$).

$$CF_{EPID:Dose}(x,y) = \frac{Dose_{dref} (cGy)}{Pixel(x,y)} \quad (1)$$

EPID calibration factors were subsequently applied to all measured images for conversion of pixel values to dose (cGy).

2.3. IMRT Fluence map generation

Dose fluences were generated for each IMRT patient field using XiO v4.64 and Monaco v3.1 planning systems (Elekta AB, Stockholm, Sweden). XiO uses a superposition algorithm for dose computation whereas Monaco dose calculation is based on a Monte Carlo algorithm.

QA fields were created by transferring the patient plan to a virtual water phantom with dimensions 40 x 40 x 40 cm on XiO, and onto a CT scan of a solid water phantom with dimensions of 30 x 30 x 30 cm for Monaco (due to software restrictions, Monaco cannot calculate dose on a virtual phantom).

Gantry, Collimator and Couch angles were set to zero degrees (0°) planar dose corresponding to $d_{ref}$ for EPID QA beams and at a depth of 3.0 cm for MapCHECK QA beams. Beams were exported at these depths for EPID and MapCHECK plans respectively.

2.4. IMRT Analysis

IMRT field-by-field comparisons were performed using Gamma Analysis with clinical criteria of 3 cGy / 3 mm, and a 10% low dose threshold. A minimum of 95% of points passing the criteria was a
requirement for plan approval. The IMRT suite in RIT v5.3 (Radiological Imaging Technology, Colorado Springs, USA) was used for Elekta iViewGT Gamma Analysis. OmniPro I’mRT (IBA Dosimetry GmbH, Schwarzenbruck, Germany) is a pre-treatment verification system for IMRT and rotational therapies and was used for Siemens OptiVue 1000ST Gamma analysis. Different programs were used for IMRT comparisons due to compatibility issues with the different vendor image formats.

3. Clinical Results
IMRT QA fields for each patient were measured with the EPID and the MapCHECK diode array and compared to TPS-generated fluence maps at calculation depths stated in Section 2.4. The percentage pass rate presented in this paper is an average Gamma Analysis result for all treatment fields in an individual patient plan.

EPID vendor-type, beam energy, and the percentage of pixels passing the Gamma criteria of 3 cGy / 3mm with EPID and MapCHECK systems is presented in table 2 for 6 and 10 MV IMRT fields. Note that 10 MV fields were measured with the OptiVue 1000ST only as the iViewGT cannot currently acquire 10 MV images. The delivery method for all listed patients was Step-and-Shoot, with the exception of Patient 9 having a dynamic MLC delivery.

Table 2: Gamma Analysis results for EPID and MapCHECK IMRT QA.

| Patient | Treatment Site | Machine | Energy (MV) | EPID  | MapCHECK |
|---------|----------------|---------|-------------|-------|----------|
| 1       | Hypopharynx    | Siemens | 6           | 99.3  | 98.4     |
| 2       | Head & Neck    | Siemens | 6           | 98.5  | 100.0    |
| 3       | Base of Tongue | Siemens | 6           | 98.6  | 99.3     |
| 4       | Head & Neck    | Siemens | 6           | 99.4  | 98.5     |
| 5       | Tonsil         | Siemens | 6           | 99.4  | 99.2     |
| 6       | Nasopharynx    | Siemens | 6           | 97.5  | 99.1     |
| 7       | SCC            | Siemens | 6           | 97.4  | 98.8     |
| 8       | Head & Neck    | Elekta  | 6           | 97.8  | 99.0     |
| 9       | Head & Neck    | Elekta  | 6           | 97.2  | 99.6     |
| 10      | Sacrum         | Elekta  | 6           | 95.5  | 98.2     |
| 11      | Prostate Bed   | Siemens | 10          | 96.5  | 97.2     |
| 12      | Anus           | Siemens | 10          | 97.6  | 99.5     |
| 13      | Anus           | Siemens | 10          | 96.6  | 96.9     |

Gamma Analysis results for IMRT QA fields measured with the EPID were compared to Gamma analysis results for fields measured with the MapCHECK. Pass rates for the EPID were comparable to the MapCHECK using clinical criteria of 3 cGy / 3mm. All EPID results for the total treatment were within a maximum of ±2.4% from the MapCHECK gamma analysis results. The average percentage of pixels in a treatment plan complying with gamma criteria was over 95% in all cases tested.

2 out of 86 EPID and 3 out of 86 MapCHECK measured beams failed the 95% pass rate. One of these beams did not pass either measurement method.

4. Discussion and Conclusion
A simple EPID dosimetry procedure was implemented and tested for clinical IMRT fields using a variety of common equipment and techniques, including both Step and Shoot and dynamic-MLC delivery techniques, Siemens and Elekta linear accelerators with a-Si EPIDs, Xio and Monaco treatment planning systems, and 6 MV and 10 MV energies.
Using a Gamma Criteria of 3 cGy / 3mm for IMRT field comparison, all patient plans had an average Gamma pass rate above 95%. EPID results agreed with the MapCHECK diode array with an average difference of 0.7% and a maximum difference of 2.4% in gamma pass rates.

Results from this study indicate that the EPID IMRT QA procedure can be used as an accurate and reliable tool for per-patient pre-treatment QA across different platforms and delivery techniques. Further assessment is required to determine the procedure efficiency compared to the current standard method, and to implement the system across multiple-departments with a still wider range of vendor equipment.

5. References
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