

A multi-configurational cylindrical phantom based evaluation of patient-specific IMRT QA tools

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Abstract. A custom in-house built multi-purpose phantom has been designed and built to investigate the integrity of the 2D Matrixx ion chamber (Scanditronix-Welhoffer, Bartlett, TN) and 3D electronic portal image device (EPID) techniques employed for patient specific IMRT delivery QA at our centre. Single ion chamber, EBT3 film and FXG gel dose measurements from the common phantom system were found to be consistent with the Matrixx and EPID measurements except in the limit of highly modulated plan deliveries.

1. Introduction

Intensity modulated radiation therapy (IMRT) has become a standard treatment approach for a number of cancer sites. Quality assurance (QA) of IMRT dose is considerably diverse, ranging from simple independent point dose calculations, to complex measurements using different 2D and 3D dosimeters. These QA tools/tasks may be utilized together or on their own, depending on the IMRT technique complexity and level of past clinical experience for that technique. At our centre, we use a commercial 2D matrix ion chamber array and an EPID based dose prediction protocol¹ for patient specific IMRT delivery QA. Gel dosimetry has also been used when we introduce and validate new IMRT techniques. While these different approaches complement each other, they often differ slightly in their response, and it would be useful to better understand the factors that give rise to these differences. The purpose of this work is to implement a common phantom system to compare 2D and 3D dose data from different IMRT QA measurement tools. The system was made as simple as possible to remove possible variations that occurred because of phantom characteristics.

2. Materials and Methods

2.1. IMRT QA Tool Comparison

The IMRT QA tools under consideration in this study were: a) Single ion chamber (Capintec PR-05P 0.07 cc/Capintec electrometer); b) 2D Matrixx ion chamber; c) Gafchromic EBT2/3 film (ISP, Wayne, NJ); d) EPID based fluence measurement and dose prediction algorithm¹; and e) Fricke-xylenol orange-gelatin (FXG) based gel dosimeter with optical CT readout². The EPID based dosimetry system (EPIDOSE) utilizes the approach developed by Ansbacher *et al.*¹, where fluence is measured using an MV imager, with nothing in the beam. A dose algorithm then is applied to the Dicom fluence data, back-projecting 3D dose to a virtual cylindrical phantom of 20.4 cm diameter.



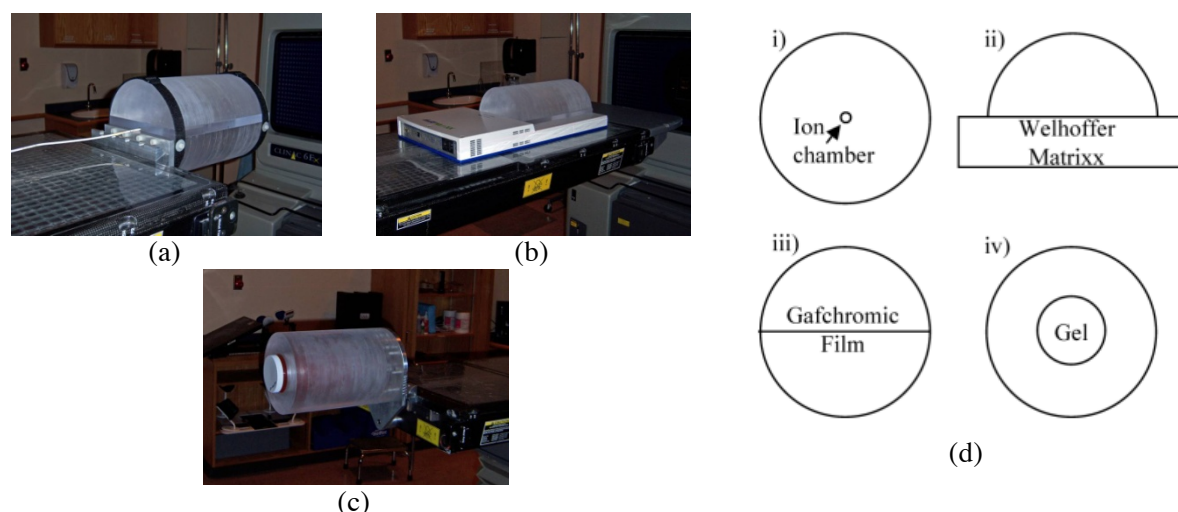


Figure 1: (a) Photographs of the phantom on the treatment unit with ion chamber and film, (b) 2D Matrixx, and (c) 3D FXG gel. (d) Cross-sections of the different configurations. The EPIDOSE configuration is not shown as it is a virtual phantom approach.

We have constructed an equivalent 20.4 cm diameter, 30 cm long density acrylic phantom for comparison of the various test tools to the EPIDOSE measurement geometry. Several versions of the cylindrical phantom have been constructed, all with same overall size, but with different inner configurations to accommodate the various dosimeters. Photographs of selected set up geometries on a Varian linac (Varian Medical Systems, Palo Alto, CA), and schematic cross sections of the different configurations are shown in Fig 1. The CT number-to-electron density calibration was adjusted slightly to model more precisely the known electron density of the acrylic phantom material. All plans were calculated in Eclipse (Varian Medical Systems) and delivered on a Clinac 2100iX linear accelerator to one or more phantom configurations. The intention was to begin with simple fields and simple IMRT patterns to provide baseline data for comparison, then move to studying more clinically relevant deliveries

Each dose measurement was compared against the corresponding Eclipse dose using commercial software designed for that dosimeter. Matrixx and film measurements were analyzed using Wellhoffer QA software (OmniPro v 1.6.0002-2008-03-12). EPIDOSE dose was compared using MATLAB (Mathworks, Newark, NJ) based software provided by Ansbacher. The reconstructed gel dose data from the VistaTM optical CT scanner (Modus Medical Devices Inc, London, ON), was converted to Dicom format, and compared to Eclipse within the CERR environment (Computational Environment for Radiotherapy Research, Washington State University, St.Louis, MO).

3. Results

3.1. Absolute Dosimetry

Table 1 shows the results of absolute point dose comparisons between dosimeter measurements and calculated dose from Eclipse. The measurements were obtained from plan deliveries on a single linac with appropriate corrections (temperature, pressure, readings normalized to a 10 x 10 cm² field reading under reference conditions, etc.). Good agreement is observed between the dosimeters except for the highly modulated sliding window plans, where EPIDOSE reads low and Matrixx reads high.

3.2. 2D/3D Comparisons

2D and 3D comparison data are shown in Fig.2 for a test prostate delivery. The film data were acquired using EBT2 film, and the disagreement recorded in the film fiducial mark regions was excluded from the analysis. Figure 3 shows the dose data from the delivery of another prostate plan to the Matrixx, with an EBT3 film inserted beneath the phantom material placed on the Matrixx.

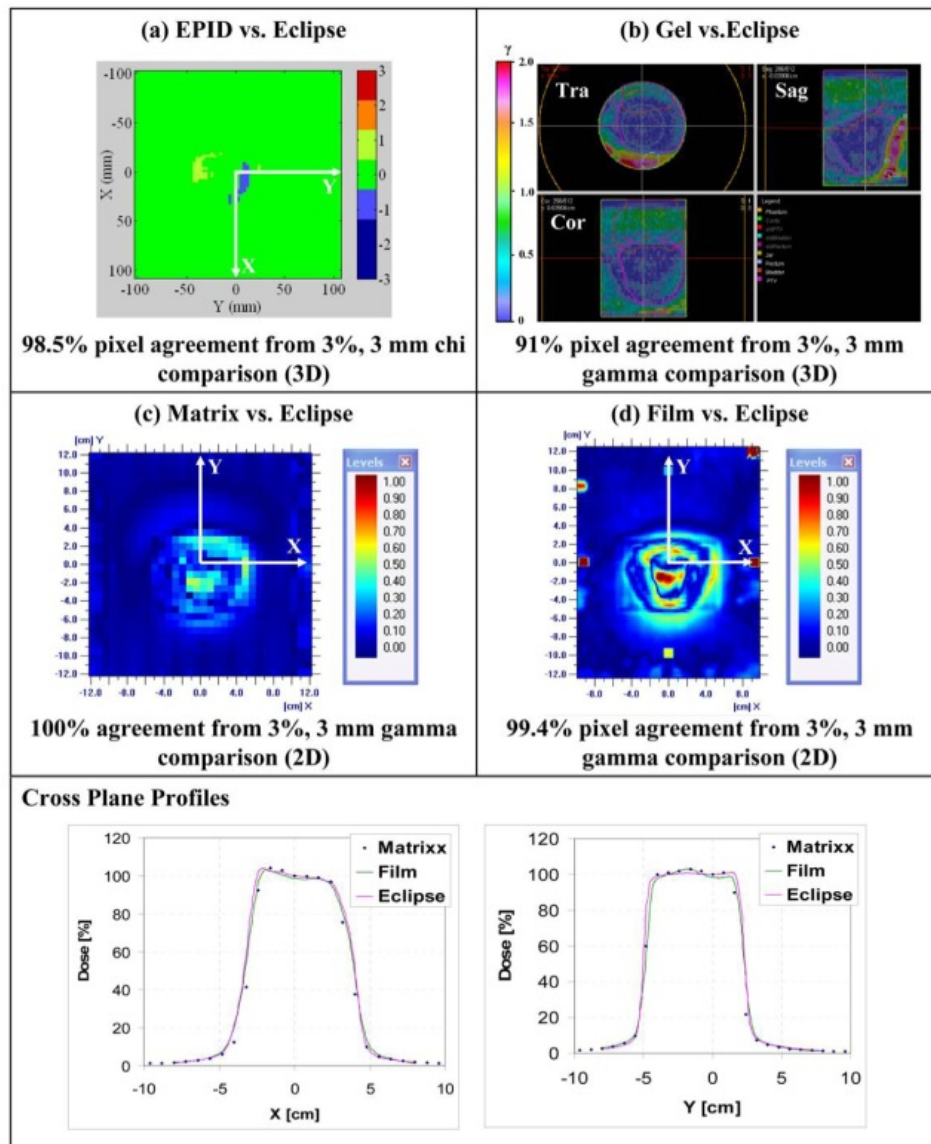


Figure 2: Dose comparisons for a prostate IMRT plan using different dosimeter tools. Dose evaluation maps for EPIDOSE, Matrixx and EBT2 film are for the coronal plane.

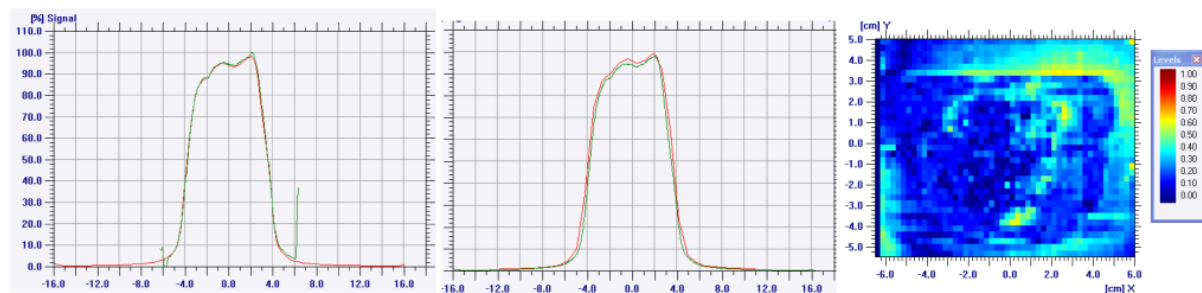


Figure 3: (left) EBT3 film (green) and Eclipse (red) dose profiles of a test prostate delivery, (centre) Matrixx (red) and Eclipse (green) dose profiles of the same delivery (on the Matrixx ion chamber measurement plane, which is 4 mm below the film plane), and (right) a 3%, 3 mm 2D gamma comparison showing 100% agreement between film and Eclipse planar dose data.

Table 1: Initial absolute dose comparisons against Eclipse for a fixed point at/near isocentre

Plan	Matrixx	EPID	Chamber	Film	Gel
10 x 10 cm ² open	-0.7	1.2	-0.8	-0.9	-
2 mm fixed width sliding window	5.8	-5.1	1.7	-1.7	-
5 mm fixed width sliding window	3.7	-3.0	0.04	-	-
20 mm fixed width sliding window	0.6	-0.3	-0.7	2.6	-
10 x 10 cm ² open (7 field)	n/a	1.0	-1.2	-	-
6 x 6 cm ² open (7 field)	n/a	0.9	1.8	-	1.0
5 mm fixed width sliding window (7 field)	n/a	-3.4	0.5	0.2	-
5 mm fixed width sliding window (7 field)	n/a	-0.1	-0.5	-	-
Prostate Plan at nominal gantry angles (7 fields)	n/a	-0.8	-1.6	-2.4	-0.5
Prostate Plan with gantry fixed at zero (7 fields)	-0.2	-0.6	-1.7	-1.9	-

4. Discussion & Conclusions

The data reported in table 1 give good indication of the absolute measurement capabilities of film and gel dosimetry. The greatest differences between measurement and plan dose (at a point set at, or near, isocentre, as dictated by the different measurement configurations) were observed in the Matrixx and EPID measurements of narrow sliding window deliveries. In determining the source of the Matrixx differences, film and ion chamber measurements (table 1, Fig.3) strongly suggest that the result is, in fact, a Matrixx over-response and not an under-calculation of Eclipse dose. This is consistent with the literature, which reports several factors contributing to an over-response of the Matrixx to highly modulated deliveries^{4,5}. For the EPID sliding window measurements, it is possible that the observed under-response could be due to variable response of the imager to scatter dose and/or the limitations of the EPIDOSE reconstruction model (which has fitted parameters based on open field data)¹.

Some variations were observed in the EBT2 film data (see profiles in Fig.2), which after careful evaluation of scanner and film performance, have been mainly attributed to non-uniform film response. EBT3 film was investigated as an alternative, and found to be more reliable in its dosimetry. The disagreement in the low-to mid dose posterior region of the gel dosimeter for the prostate delivery (Fig.2) has been identified as primarily due to a resolvable issue in the gel calibration. Another set of gel and film measurements are forthcoming.

Overall, the Eclipse and measurement data from the different dosimeters are in good agreement for simple open field and relatively low modulation prostate IMRT deliveries. The value of the common cylindrical phantom system has also been demonstrated. Next steps include a similar cross-comparison for more highly modulated complex head and neck IMRT deliveries.

5. Acknowledgements

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6. References

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