Dosimetric Comparison of a-Si 1200 and a-Si 1000 Electronic Portal Imager for Intensity Modulated Radiation Therapy (IMRT)

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Abstract

Aim: This study investigates the dosimetric impact of a-Si 1200 over a-Si 1000 portal imager for 6 MV photon beam of a Varian Amorphous Silicon Electronic Portal Imaging Device (a-Si EPID) installed on Edge and Novalis TxLinac.

Materials and Methods: The performance of an a-Si EPID 1200 was assessed and compared to its performance with a-Si EPID 1000 and dose measurements using an ionization chamber. This study was conducted for 6MV photon energy and the EPID performance was assessed as function of the delivered dose, dose rate, field size, SDD effect, Ghosting effect, Backscatter arm shielding impact and intensity-modulated radiation therapy fields.

Results: The dose response for a-Si 1200 was within 0.5% for low MU (2-10) as compared to 1.4% for a-Si 1000 portal imager and less than 1% for both the imager above 10 MU. The output factor variation for $25 \times 25 \text{ cm}^2$ was 1.3% for a-Si 1200 and 3.8% for a-Si 1000 when compared with ionisation chamber. The ghosting was measured to be 0.2% for a-Si 1200 as compared to 0.8% for a-Si 1000 portal imager. There is a significant improvement in a-Si 1200 portal image due to backscatter shielding material attached to the back of the panel of a-Si 1200 portal imager.

Conclusion: The new aS1200 detector showed a significant dosimetric improvement when compared with previous aS1000 hence providing more accurate measurements for pre-treatment patient specific Quality Assurance (QA).

Keywords: Electronic portal imager; Dosimetry; IMRT; Quality assurance

Introduction

In the recent years IMRT in clinical routine has been rapidly increasing due to its better target coverage with normal tissue sparing. The complexity of IMRT demands accurate quality assurance before the treatment delivery. Film dosimetry for pre-treatment verification of patient-specific IMRT dose distribution is the gold standard due to its high resolution [1-4]. But the dose response of film is affected by processing conditions hence films are gradually being replaced by two-dimensional (2D) detector arrays due to their ease of use and instant results. Dosimetric characteristics and clinical implementation of 2D detector arrays consisting of a large number of ionization chambers or diodes have been reported for pre-treatment verification of IMRT plans [5-10]. A more efficient tool for pre-treatment QA is the EPID as it is mounted on linac, providing real time feedback to the user. Although the primary purpose of EPID is to verify patient positioning, but with the introduction of on board imagers for image guidance the EPID has been more utilised for machine QA and pre-treatment patient specific QA [11-14]. Dosimetry using EPIDs or portal dosimetry has received considerable attention recently due to its relatively high-resolution of 0.392mm amorphous silicon (a-Si) flat-panel detector [15-18]. Several authors have extensively studied the dosimetric properties of a-Si 500 and a-Si 1000 EPID and its application in IMRT [19-25]. Varian has recently released a-Si 1200 portal imager with larger area, high resolution of 0.336 mm and improved backscatter for dosimetry. Varian has adapted a-Si 1200 portal imager for the use of FFF beams without saturation at any source to detector distance [26-27].

Recently we commissioned a-Si1200 EPID and Portal Dose Prediction (PDP) algorithm in Eclipse (Varian Medical Systems, Palo Alto, CA) Treatment Planning System (TPS) for portal dosimetry. This study aims to compare the dosimetric properties of new a-Si

1200 EPID with Varian Edge linac along with a-Si 1000 portal imager. The dosimetric factors include delivered dose, dose rate, Source to Detector Distance (SDD) effect, field size dependence, ghosting effect, impact of backscatter shielding over a-Si 1000 portal arm and common IMRT fields. The responses were compared with the measurements of calibrated 0.6cc volume ionisation chamber.

Materials and Methods

In this study all the measurements were performed on a-Si 1200 EPID with Varian Edge linear accelerator and a-Si 1000 portal imager attached with Novalis Tx accelerator. The high resolution a-Si1000 EPID, available for patient set-up verification used in this study has arrays of light sensitive amorphous-Si photodiodes arranged in $40 \times 30 \text{ cm}^2$ active detector area with 1024×768 pixels, and pixel pitch of 0.390 mm. The a-Si 1200 EPID detector was released recently and has an active area of $40 \times 40 \text{ cm}^2$ with 1190×1190 pixel arrays and pixel pitch of 0.336 mm. From outside, the imager looks the same [26]. The change is hidden behind the MV imager's cover as shown in Figure 1.

All the measurements were done for 6 MV photon beam. The comparison of a-Si 1200 and a-Si 1000 are given in Table 1.

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EPID Model	a-Si 1000	a-Si 1200
Max irradiated area (cm ²)	30 × 40	43 × 43
Active area (cm ²)	30 × 40	40 × 40
Total pixel matrix	768 × 1024	1280 × 1280
Active dosimetry matrix	768 × 1024	1190 × 1190
Pixel size (mm)	0.39	0.34

Table 1: Comparison of a-Si 1200 and a-Si 1000 portal imager.

Dosimetric properties of electronic portal imaging device

Linearity with delivered dose: To verify linearity of EPID dose response versus delivered dose detector was irradiated with a dose range of 2, 3, 4, 5, 8, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 200, 300, 500 and 600 monitor units for a field size of 10 cm × 10 cm² for 6 MV at fixed dose rate 600 MU/min with imager at 105 cm. The mean pixel value of 10 × 10 matrix measured at the centre of the field was measured and graph was plotted against MU.

Dose rate linearity: The linearity of EPID to dose rate was also verified in order to rule out any variations on EPID signal due to dose rate. A dose of 100 MU was delivered for 6 MV beam with a dose rate of 100 to 600 MU/min for 10 × 10 cm² field size.

Field size dependence: Open square fields of size: 3 cm², 4 cm², 5 cm², 8 cm², 10 cm², 12 cm², 15 cm², 20 cm² and 25 cm² were delivered with 50 MU with 400 MU/min at 105 cm. Results were normalized to that response for 10 × 10 cm² field size. The results were compared with those of ionisation chamber measurements.

Ghosting effect: Ghosting is artefact in the image produced due the signals being present in frames subsequent to the frame in which it was generated. It was measured in a similar manner to that employed by Van Esch et al. and Greer and Popescu [28-30]. To assess the existence of memory effect for portal imagers the detector was exposed for 500 MU in 5 × 5 cm² static field immediately followed by delivery of 10 MU in 15 × 15 cm² static field. The interval between the two consecutive images was 15 sec. Then after a gap of 15 min another 10 MU was delivered for 15 × 15 cm² field and was kept as a reference for comparison of profile across 15 × 15 cm² field.

Effect of SDD: To evaluate the impact of SDD on EPID the detectors were irradiated with SDD of 105 cm, 105.5 cm, 106 cm, 106.5 cm, 107

cm, 107.5 cm, 108 cm, 109 cm, 110 cm with 100 MU and a field size of 10 × 10 cm².

Backscatter impact: To verify the effectiveness of a-Si 1200 backscatter shielding layers, cross plane and in plane profiles were compared through the central axis for different field sizes ranging from 2 × 2 to 27 × 27 cm².

Intensity modulated radiation therapy delivery: A clinical dynamic IMRT plans were delivered using 6 MV and a dose rate of 400 MU/min on both the portals and the gamma evaluations of measured dose against TPS doses were performed for 20 IMRT cases. All the cases were planned in Eclipse Planning system and with same planning constraints for both the linac.

Results

Linearity with delivered dose

Both the detectors showed excellent linearity with monitor units ranging from 2 MU to 600 MU when compared with ion chamber as shown in Figure 2. The dose response for a-Si 1200 was within 0.5% for low MU (2-10) as compared to 1.4% for a-Si 1000 portal imager and less than 1% for both the imager above 10 MU.

Linearity with dose rate

The detector panel did not exhibit any dose rate saturation in response to the dose rate range 100 to 600 MU/min as shown in Figure 3. The a-Si 1200 imager showed a better agreement with ionisation chamber as compared to a-Si 1000 portal imager.

Field size dependence

The field size output factors of both the EPID's and farmer type chamber are shown in Figure 4. Variations are larger for field size >20

× 20 cm for a-Si 1000 as compared with a-Si 1200. The variation for 25 × 25 cm was 1.3% for a-Si 1200 and 3.8% for a-Si 1000 when compared with ionisation chamber.

Effect of SDD

Both the detectors showed similar response when compared with ion

chamber on SDD variation as shown in Figure 5.

Ghosting effect

The residual of foregoing irradiation of 5 × 5 cm field exposed with 500 MU in the image of larger field 15 × 15 acquired immediately with 10 MU for both the imagers are shown in Figures 6a and 6b. The

Figure 7: In plane profile to examine impact of backscatter shielding on a-Si 1200 and a-Si 1000 portal imager.

Cases	a-Si 1200 Portal dosimetry –Gamma values with 3% 3mm criteria			a-Si 1000 Portal dosimetry –Gamma values with 3% 3mm criteria		
	Area Gamma <1	Max Gamma	Avg Gamma	Area Gamma <1	Max Gamma	Avg Gamma
1	99.5	2.13	0.26	95.1	2.33	0.4
2	98.8	2.27	0.3	95.8	2.8	0.4
3	98.6	2	0.25	95.3	3	0.35
4	99.3	1.9	0.24	96.3	2.7	0.35
5	99.7	1.3	0.26	97	2	0.35
6	98.5	1.9	0.37	98	2.5	0.5
7	99.8	2	0.32	98.5	3.1	0.45
8	98	2.2	0.24	98	2.5	0.38
9	99.4	2.1	0.32	98	2.7	0.5
10	99.9	1.5	0.33	97	1.7	0.46
11	97.7	1.4	0.26	95.5	1.8	0.38
12	98.1	1.89	0.22	97	1.9	0.3
13	99.8	1.56	0.23	98	1.7	0.32
14	98.5	1.7	0.36	95	1.9	0.45
15	99.5	1.9	0.29	96.5	2.2	0.4
16	98.5	2.1	0.3	96	2.4	0.45
17	97.2	3.1	0.28	95	3.5	0.38
18	98.6	2.5	0.31	96	2.9	0.51
19	97.5	1.5	0.24	95.7	1.8	0.44
20	97	1.3	0.22	95.1	1.9	0.42
Avg	98.70	1.91	0.28	96.44	2.37	0.41
SD	0.905	0.437	0.045	1.174	0.528	0.060

Table 2: Patient specific QA results for 20 IMRT cases.

ghosting was measured to be 0.2% for a-Si 1200 as compared to 0.8% for a-Si 1000 portal imager.

Backscatter impact

The in plane profiles for maximum field size 27 × 27 is shown in Figure 7. There is a significant improvement in a-Si 1200 portal imager when compared with a-Si1000 portal imager due to backscatter shielding material attached to the back of the panel of a-Si 1200 portal imager. As the field size reduces, so is the backscatter contribution as seen in Figure 7. This is visible in in plane direction in the upper half of imager panel where the arm is mounted on the metal bar which provides the largest source of backscatter.

IMRT delivery

The results of gamma evaluation for 20 dynamic IMRT cases were

tabulated as shown in Table 2. There was an improvement in the area gamma values, average gamma and maximum gamma for a-Si 1200 over a-Si 1000 portal imager. The area gamma for a-Si 1200 portal imager was 98.70% as compared with 96.44% for a-Si 1000 portal imager.

Discussion

Before using any dosimetric tool for clinical purpose there is a need to study the dosimetric characteristic of that tool. Due to their excellent dosimetric characteristics and easiness to use the portal dosimetry and 2-D array have been widely adopted as patient specific QA tool. The dosimetric properties of a-Si 1200 proved its worth over a-Si 1000, film and other dosimetric system. Better understanding of the dosimetric characteristics is required for the efficient use and development of effective measurement tools for better accuracy.

In this study, the linearity of EPID response was within 0.5% for low MU (2-10) as compared to 1.4% for a-Si 1000 portal imager and less than 1% for both the imager above 10 MU. This shows an improvement over previous reports for a-Si 1000 portal imager and other vendor EPID systems [31-33]. The dose rate and field size dependence of a-Si 1200 imager correlated well with ionization chamber measurement as compared with a-Si 1000 portal imager. Due to the backscatter arm shielding impact the output factor reduced for a-Si 1200 for larger field size and a variation of 1.3% for a-Si 1200 was observed as compared with 3.8% for a-Si 1000. The total ghosting effect was found to be <0.2% for a-Si 1200 when compared with a-Si 1000. Our results are comparable to the results obtained by Reilly et al. [34-37]. This must be considered negligible for the application of pre-treatment dosimetric treatment verification.

The symmetry of the profiles for a-Si 1200 EPID was considerably improved over the a-Si 1000 imager, indicating the effectiveness of backscatter shielding in the new system. The impact of backscatter was previously studied on a-Si 1000 imager [38-41]. In this study, the gamma values obtained with a-Si 1200 portal dosimetry were found to be more consistent compared to those obtained with a-Si 1000 portal dosimetry due the improvement in dosimetric characteristics of a-Si 1200 portal imager.

Conclusion

The new aSi1200 detector showed a significant dosimetric improvement when compared with previous aSi1000 hence providing more accurate measurements. The ghosting effect has reduced and the impact of support arm backscatter is negligible with significant differences observed in comparison of IMRT gamma results and it allows the new EPID to be applied for pre-treatment QA.

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