

Dosimetric Comparison of aSi1000 EPID and ImatriXX 2-D Array System for Volumetric Modulated Arc and Intensity Modulated Radiotherapy Patient Specific Quality Assurance

Jayesh K., Ganesh T., Suganthi D., Mohan R., Rakesh C. J., Sarojkumar D. M., Jacob S. J.

Abstract—Prior to the use of detectors, characteristics comparison study was performed and baseline established. In patient specific QA, the portal dosimetry mean values of area gamma, average gamma and maximum gamma were 1.02, 0.31 and 1.31 with standard deviation of 0.33, 0.03 and 0.14 for IMRT and the corresponding values were 1.58, 0.48 and 1.73 with standard deviation of 0.31, 0.06 and 0.66 for VMAT. With ImatriXX 2-D array system, on an average 99.35% of the pixels passed the criteria of 3%-3 mm gamma with standard deviation of 0.24 for dynamic IMRT. For VMAT, the average value was 98.16% with a standard deviation of 0.86. The results showed that both the systems can be used in patient specific QA measurements for IMRT and VMAT. The values obtained with the portal dosimetry system were found to be relatively more consistent compared to those obtained with ImatriXX 2-D array system.

Keywords—Gamma, IMRT, QA, TPS, VMAT.

I. INTRODUCTION

INTENSITY modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) are advanced form of 3D conformal radiation therapy in which non uniform intensity radiation are used to get uniform desired dose distribution to the target volume with adequate sparing of the near-by critical structures. The portal dosimetry system and 2-D array system are widely using as relative dosimetric detectors for the planar dose comparison of TPS Vs measured doses and it replaced the film dosimetry because of their short

Jayesh. K., PhD scholar, is with Department of Physics, Karunya University, Coimbatore, India (corresponding author: phone: +91 9746464759, e-mail: jayankpala@hotmail.com).

Ganesh. T., Senior Medical Physicist, is with Department of radiation Oncology, King Fahad Specialist Hospital, Dammam, KSA.

Mohan. R., Senior Medical Physicist, is with Department of radiation Oncology, King Fahad Specialist Hospital, Dammam, KSA.

Rakesh. C. J., Senior Medical Physicist is with Department of radiation Oncology, King Fahad Specialist Hospital, Dammam, KSA.

Sarojkumar. D. M, Radiation Oncologist, is with Department of radiation Oncology, King Fahad Specialist Hospital, Dammam, KSA.

Jacob. S.J, Radiation Oncologist, is with Department of radiation Oncology, King Fahad Specialist Hospital, Dammam, KSA.

Suganthi. D., Associate Professor and Head, is with Department of Physics, Karunya University, Coimbatore, India.

acquisition time, less time consuming, consistency and easy to use[1,2]. Availability of new detectors with improved characteristics, better treatment calculation algorithms, modern treatment delivery machines and modes of delivery, made possible to improve on the conventional QA standards [3-9]. The validity of aSi1000 EPID, 2D array detectors and 3D verification systems as an ideal dosimeter for IMRT patient specific QA are still subject of controversy in the literature and conflicting data have been reported [10, 11]. This work aimed to compare the dosimetric characteristics of aSi1000 portal imager and ImatriXX 2-D array system and to validate the detectors for dynamic IMRT and VMAT patient specific QA.

II. MATERIALS AND METHODS

In this study all the measurements were performed in the Varian Clinac iX linear accelerator (LINAC). The aSi1000 EPID is a flat panel X-ray imager with large area active matrix readout structure, made up of phosphor or photo conductor. Here each pixel in the matrix consists of aSi photo cathode and a thin film transistor (TFT). The associated electronics with the TFT switches enables the charge capture readout. The image acquisition system with fast readout electronics enable up to 30 frames per second in aSi 1000 EPID. The resolution of aSi 1000 EPID is upto 0.39mm. The ImatriXX 2-D array system consists of 1020 parallel plate ion chamber arranged in a 32x32 grid, with an inter detector spacing of 7.619 mm. Each detector is having a diameter of 4.5 mm, height 5 mm and chamber volume 0.02 cc.

To verify the linear response, detectors were irradiated with a dose range of 2, 3, 4, 5, 8, 10, 15, 20, 25, 30, 35, 50, 75, 100, 150, 200, 300, 400 and 500 MUs (in monitoring units). The responses were compared with the measurements of 0.6cc, 0.125 cc and 0.1 cc volume ion chambers. As the EPID signal is calibrated for fixed dose rate the fluctuations in dose rate can potentially influence the response of EPID as in case of dynamic IMRT and VMAT. So the linearity of EPID to dose rate was also verified. In this study dose of 100 MU was delivered, integrated image was acquired for 6 MV beam with dose rates of 100 MU/min to 600MU/min. The ImatriXX and

ion chambers response to different dose rates were also studied. Field size response of the aSi1000EPID and ImatriXX system were evaluated in comparison with ion chamber measurements, by delivering 50 MU with dose rates of 300 MU/min for the field sizes of 2x2 cm², 3x3cm², 4x4 cm², 5x5 cm², 6x6 cm², 8x8 cm² · 10x10 cm², 15x15 cm² and 20x20 cm². To evaluate the effect of SDD on the EPID, ImatriXX and ion chamber measured dose, the detectors were irradiated with SDD of 105,105.5, 106,106.5, 107,107.5,108,109 and 110 cm with 100 MU and field size of 10x10cm². The measured values were plotted against the varying SDDs. The short term stability and temperature dependence of the detectors were also evaluated for 10x10 cm² field sizes, delivering 100MU over a short period of ten days.

The Gamma evaluations (% difference and DTA) of measured dose against TPS calculated doses were performed for ten dynamic IMRT cases with total 102 split fields and ten VMAT cases. All the cases were planned in Eclipse treatment planning system and the QA plans for absolute point dose measurements, portal dosimetry and ImatriXX system were created for the TPS calculated planar dose distributions. This created QA plans were executed in ARIA networked platform and the measured planar dose images were acquired. The calculated and measured dose for each plan was compared on the basis of 3% 3mm gamma criteria (% difference and DTA). For the portal dosimetry, area gamma >1%, average gamma and maximum gamma were measured and tabulated. For the ImatriXX system the percentage of the pixels passed the acceptance criteria 3% 3mm were calculated and tabulated. The mean and standard deviation for all the gamma parameters were calculated and compared.

III. RESULTS

In the characteristics comparison study the measured values for different monitor units were analyzed for both the detector system. Both the detectors exhibit excellent linearity with monitor unit (MU) ranging 2 MU to 500 and it was compared with the ion chamber results as shown in Fig. 1. The Fig. 2 shows the dose rate response of aSi1000 EPID and ImatriXX system in comparison with the ion chamber measurements. The detector panel did not exhibit any significant dose rate dependant saturation in response with the dose rate range 100 MU/min to 600 MU/min (< +/- 0.5 %). Fig. 3 shows the field size dependence of aSi1000EPID and ImatriXX system in comparison with the ion chamber results. The results were comparable with the 0.6 cc, 0.125cc and 0.01 cc ion chamber measurements. With values normalized to 10x10cm² field, the data sets for all detectors were similar. Detectors have shown similar response on SDD variation. The results were compared with the ion chamber measurements as shown in the Fig. 4. Both the detectors showed excellent short term stability and temperature stability as shown in the Fig. 5 and Fig. 6. For all the parameters the Karl Pearson product moment correlation coefficient showed good agreement and linear relationship with value of more than 0.9.

The results of gamma evaluation for ten dynamic and ten VMAT cases were tabulated as shown in the Table I and

Table II. In the planar dose comparison, the portal dosimetry mean values of area gamma, average gamma and maximum gamma were 1.02, 0.31 and 1.31 with standard deviation values of 0.33, 0.03 and 0.14 for dynamic IMRT and the corresponding values were 1.58, 0.48 and 1.73 with standard deviation of 0.31, 0.06 and 0.66 for VMAT. With the ImatriXX 2-D array system, on an average 99.35% of the pixels passed the criteria of 3%-3 mm with standard deviation of 0.24 for dynamic IMRT. For VMAT, the average value was 98.16% with a standard deviation of 0.86.

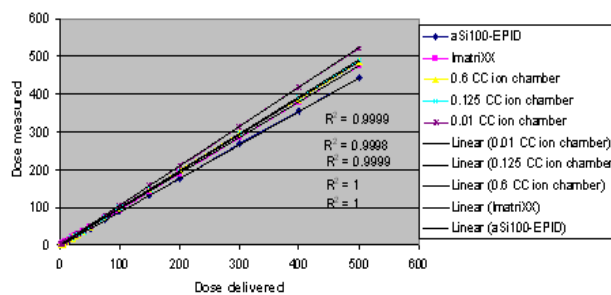


Fig. 1 Dose linearity

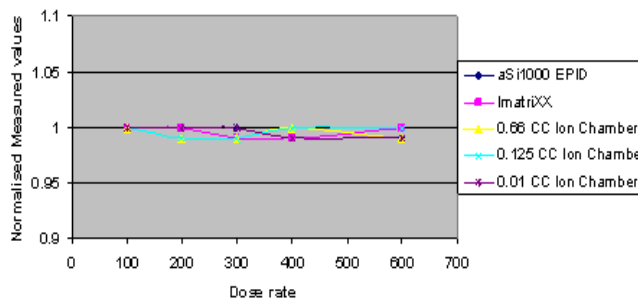


Fig. 2 Dose rate response

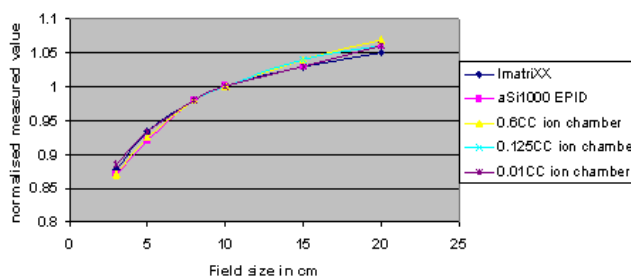


Fig. 3 Field size dependence

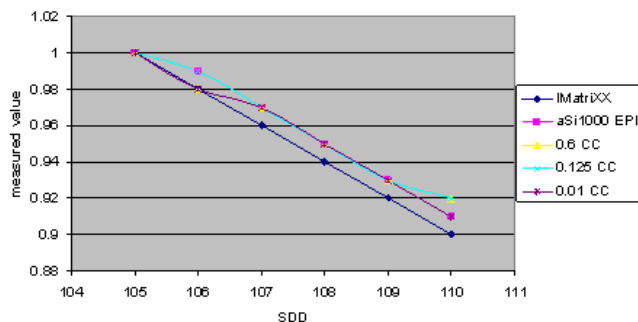


Fig. 4 Source to detector distance (SDD) dependence

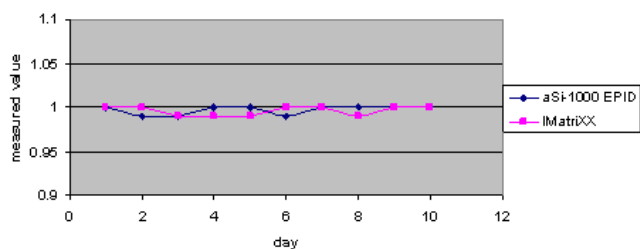


Fig. 5 Short term stability

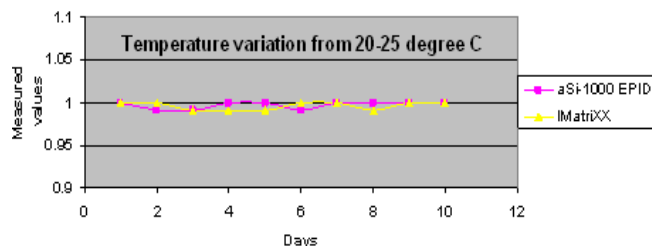


Fig. 6 Temperature stability

TABLE I
GAMMA RESULTS- TPS VS MEASURED WITH PORTAL DOSIMETRY

Cases	Portal dosimetry –Gamma values with 3%-3mm criteria					
	Dynamic IMRT			VMAT		
	Area $\gamma \geq 1\%$	Avg γ	Max γ	Area $\gamma \geq 1\%$	Avg γ	Max γ
1	0.72	0.27	1.23	1.54	0.41	1.05
2	0.63	0.28	1.04	1.88	0.51	1.26
3	0.85	0.33	1.37	1.27	0.49	1.62
4	0.85	0.28	1.27	1.02	0.44	1.51
5	1.3	0.31	1.45	1.99	0.47	1.05
6	0.79	0.29	1.23	1.61	0.43	1.21
7	0.7	0.32	1.23	1.23	0.43	1.72
8	1.45	0.32	1.48	1.87	0.48	2.11
9	1.37	0.32	1.27	1.49	0.49	2.96
10	1.54	0.39	1.56	1.9	0.65	2.84
Avg	1.02	0.31	1.31	1.58	0.48	1.73
Std dev	0.33	0.03	0.14	0.31	0.06	0.66

TABLE II
GAMMA RESULTS- TPS VS MEASURED WITH IMATRIXX

Cases	ImatriXX system- Gamma values with 3%3mm gamma criteria	
	Dynamic IMRT	VMAT
	% of pixels passed	% of pixels passed
1	99.3	98.54
2	99.12	97.58
3	99.16	98.23
4	99.23	97.47
5	99.54	98.11
6	99.32	99.55
7	99.52	97.05
8	99.86	99.61
9	99.47	97.1
10	99.04	98.38
Avg	99.35	98.16
Std dev	0.24	0.86

IV. DISCUSSION

Studies of dosimetric characteristics are essential before using any dosimetric tools for the clinical purpose. Nowadays portal Dosimetry and 2-D array verification systems are widely adopted for the patient specific QA due to their excellent dosimetric characteristics and easiness to use. Dosimetric properties of aSi1000 EPID and ImatriXX 2-D array system proved its worth over film and other dosimetric system. Better understandings of the dosimetric characteristics are required for the development of an effective and efficient algorithm and dosimetric measurement tool for the better accuracy. Both the detector system showed good response for IMRT and VMAT patient specific QA. With the introduction of aSi1000 EPID individual field verification can be done very effectively with an excellent spatial resolution. The disadvantages of the 2D array system are the low resolution of the detectors and the time taken to set up the detectors and phantom and to connect with the external computer system with analysis software. The values obtained with the portal dosimetry system were found to be relatively more consistent compared to those obtained with ImatriXX 2-D array system

V. CONCLUSION

The results showed that both the systems can be used in patient specific QA measurements for IMRT and VMAT. The EPID based IMRT and VMAT patient specific QA offer great potential for saving time and for the verification of individual IMRT fields.

REFERENCES

- [1] T.Wiezorek., M. B. Nschwedas, D. Georg and T. G. Wendt, "Dosimetric quality assurance for intensity-modulated radiotherapy feasibility study for a filmless approach." *Strahlenther. Oncol.*, vol. 81, pp. 468-74, 2005.
- [2] B F Branci, L Marrazzo and S Russo, "An inter comparison between film dosimetry and diode matrix for IMRT quality assurance." *Med. Phys.*, vol.34, pp. 1372-1379, 2007.
- [3] G J Budgell, Q Zhang, R J Trouncer and R I Mackay, "Improving IMRT quality control efficiency using an amorphous silicon electronic portal imager," *Med. Phys.*, vol.32, pp.3267-78, 2005.
- [4] P Winkler, A Hefner and D Georg, "Dose- response characteristics of amorphous silicon EPID," *Med. Phys.*; vol. 32, pp. 3095-105, 2005.
- [5] E E Grein, R Lee and K Luchka "An investigation of a new amorphous silicon electronic portal imaging device for transit dosimetry," *Med. Phys.* vol 29: pp. 2262, 2002. R. W. Lucky, "Automatic equalization for digital communication," *Bell Syst. Tech. J.*, vol. 44, no. 4, pp. 547-588, Apr. 1965.
- [6] P. B. Greer, C. C and Popescu, "Dosimetric properties of an amorphous silicon electronic portal imaging device for verification of dynamic intensity modulated radiation therapy," *Med. Phys.*, vol. 30, pp. 1618-27, 2003.
- [7] E Spezi, A L Angelini, F Romani and A Ferri, "Characterization of a 2D ion chamber array for the verification of radiotherapy treatments," *Phys. Med. Biol.*, vol. 50, pp. 3361-3373, 2005.
- [8] B V Elsevier, "Evaluation of a 2D diode array for IMRT quality assurance," *Radiother. Oncol.*, vol. 70, pp.199-206, 2009.
- [9] N Agazaryan,D S Timothy and J J Demarco, "Patient specific quality assurance for the delivery of intensity modulated radiotherapy," *J. Appl. Clin. Med. Phys.*, vol. 4, 2003.
- [10] C D Wager, "The ideal dosimeter for intensity modulated radiation therapy (IMRT): what is required?" *Jr. Phys.*, vol. 3, pp. 4-8, 2004.
- [11] W. V. Elmpt, L. Mcdermott, S. Nijsten, M. wending, *et al*, "A literature review of electronic portal imaging for radiotherapy dosimetry," *Radiother. oncol.*, vol. 88, pp. 289-309, 2008.