Evaluation of the Long-term Performance of a-Si 1200 Electronic Portal Imaging Device

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INTRODUCTION

Electronic portal imaging devices (EPIDs) have been established as two-dimensional dosimetry systems in radiotherapy. However, their long-term performance monitoring has not been thoroughly examined in literature. Quality assurance methods to monitor the entire EPID's 2D dose response must be employed to establish reliability for routine dosimetric applications and to ensure that both relative and absolute dosimetry behaviors stay within acceptable clinical tolerances.

AIM

The purpose of this research was to propose and implement techniques to monitor stability and reproducibility of the dosimetric performance of the a-Si 1200 EPID (Varian Medical Systems) over an extended period of time.

METHOD

Weekly measurements of the entire two-dimensional a-Si 1200 EPID dose response were carried out over a 24-month period between September 2020 and September 2022. The measurements were performed on two clinically used Varian TrueBeam linacs (local names "Unit A" and "Unit J"). Both imaging modes (continuous and dosimetry), and all available photon beam energies (6X, 6FFF, 10X, 10FFF and 23X) were tested.

Calibration fields (flood and dark) were measured to assess their long-term reproducibility. Standard deviation of the mean readout signal value was assessed for each individual EPID pixel. The distributions of standard deviations of measured signal across the imager plane were compared with the standard deviations of the integrated imager signal for each mode. Average standard deviation calculated among all pixels was taken as a figure of merit and reported for each linac, each beam energy, each calibration field type and each imaging mode.

Weekly measurements of the EPID response against a secondary ion chamber dosimeter (Exradin, Standard Imaging) positioned on central axis, and also an ion chamber array (MatriXX, IBA Dosimetry) were carried out to evaluate EPID response variability over the 24-month period. Measurements of the secondary absolute dosimeters were used as baselines, and the ratios of EPID readings to these measurements were analysed using standard deviation.

Pixel sensitivity matrices (PSM)s were determined and monitored for long-term constancy for both linacs using the technique proposed by Greer *et al*[1].

REFERENCES

[1]**Greer PB**. Correction of pixel sensitivity variation and off-axis response for amorphous silicon EPID dosimetry. *Med Phys 2005*; *32(12):3558–68.*

ACKNOWLEDGEMENTS

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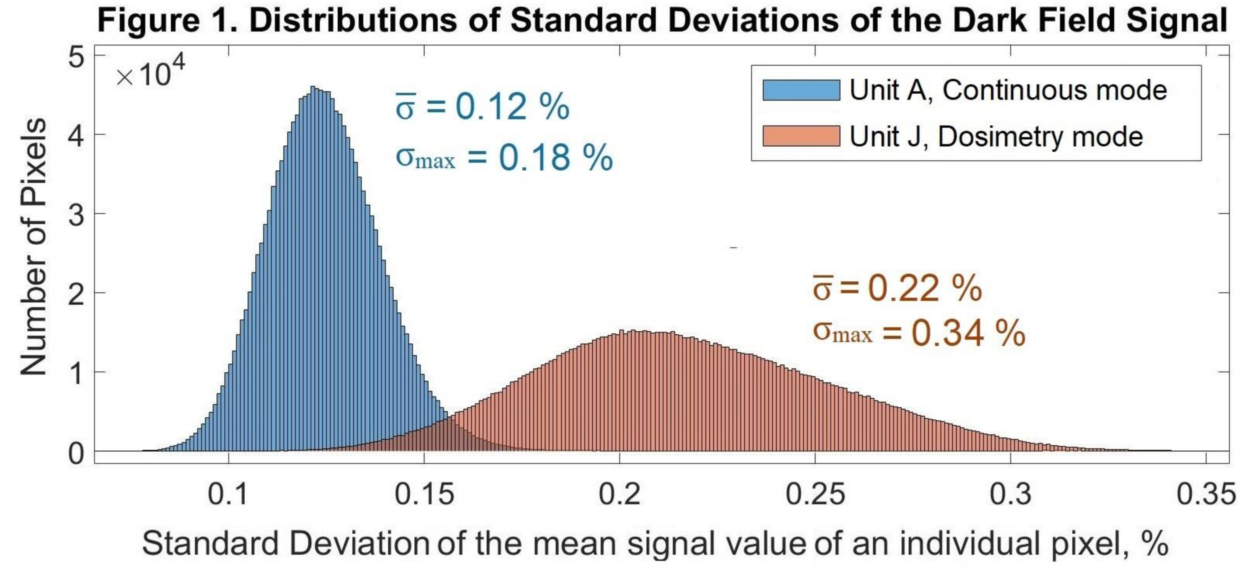
RESULTS

DARK FIELD CONSTANCY AND REPRODUCIBILITY

Dark field measurements demonstrated very good constancy. Continuous mode acquisitions had smaller mean and maximum values, and smaller range of standard deviations than in integrated mode. **Figure 1** shows distributions of standard deviations among all pixels, shown as percentage of the mean signal value of each pixel, for the best result – Unit A dark field measured in continuous mode, and the worst result – Unit J dark field measured in dosimetry mode.

Figure 1. Distributions of Standard Deviations of the Dark Field Signal



The smallest observed mean/maximum standard deviations are 0.12% and 0.18%, the greatest values are 0.22% and 0.34%, respectively.

CONSTANCY OF PIXEL SENSITIVITY MATRIX

Figure 3(a) shows pixel sensitivity profiles measured in central axis plane of Unit A at different dates. **Figure 3(b)** shows distribution of differences.

Figure 3 (a) Pixel Sensitivity Map Profiles Measured with 15 Month Interval

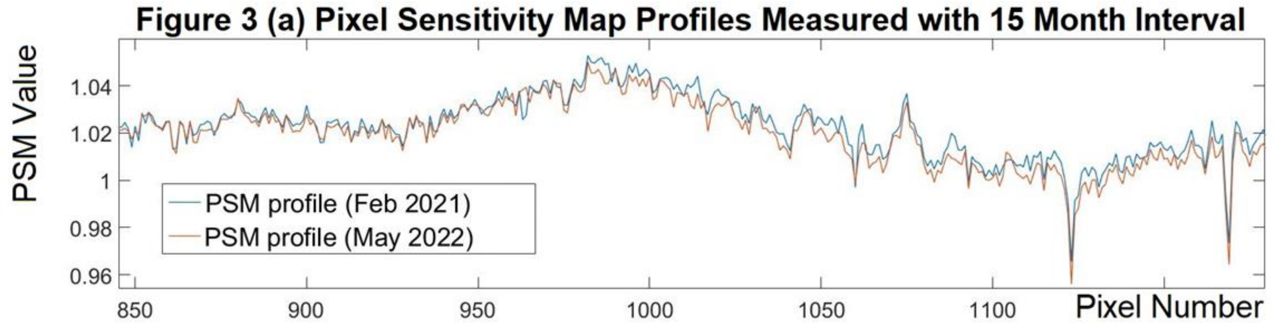
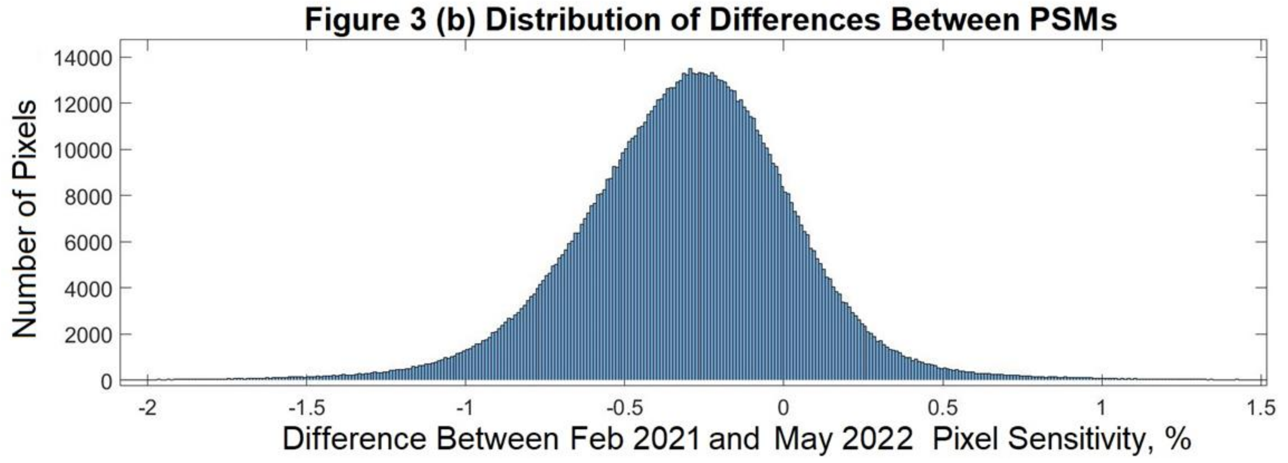


Figure 3 (b) Distribution of Differences Between PSMs



PSM measurements show average difference among pixels of 0.37% and 0.18% for Unit A and Unit J, respectively. Overall, PSM demonstrates good long-term stability with over 94% of pixels showing changes below 1%, and 100% of pixels differing by under 2% over the two-year period.

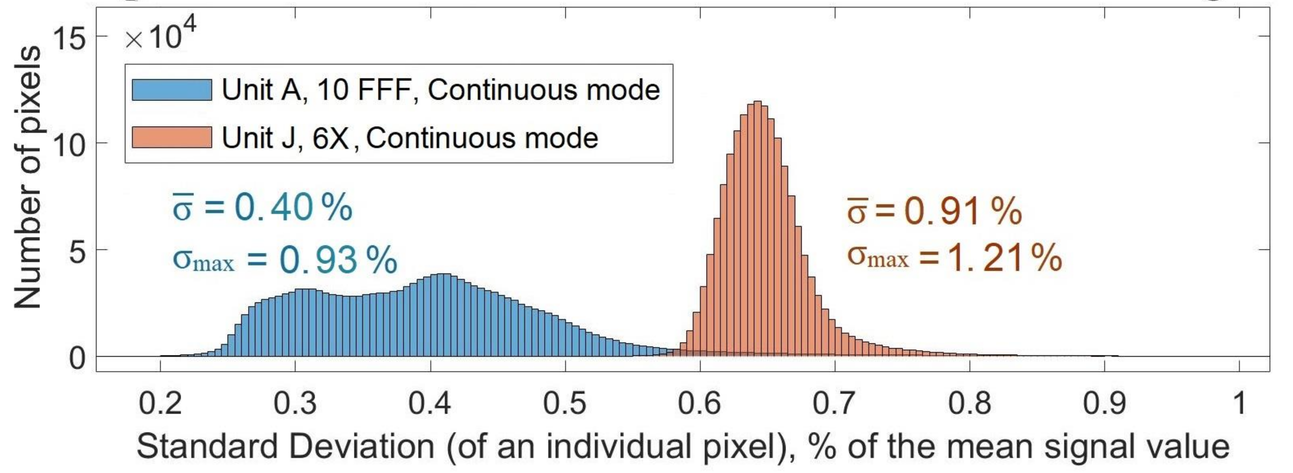
FLOOD FIELD CONSTANCY AND REPRODUCIBILITY

Flood field measurements have also demonstrated good constancy; however, standard deviations of flood field signal are greater in value and spread compared to dark field results. **Table 1** shows average standard deviations observed for each linac, beam energy, calibration field type and acquisition mode. **Figure 2** shows distributions of standard deviations of flood field signal for the smallest observed average value - 10FFF flood field measured in continuous mode on Unit A, and the largest observed average value – 6X flood field measured in continuous mode on Unit J.

Table 1. Average Standard Deviations of Flood Field Signal

Beam Energy / Imaging Mode	Unit A		Unit J	
	Dosimetry	Cine	Dosimetry	Cine
6X	0.55 %	0.81 %	0.63 %	**0.91 %**
6FFF	0.54 %	0.80 %	0.62 %	0.59 %
10X	0.56 %	0.61 %	0.61 %	0.81 %
10FFF	0.55 %	**0.40 %**	0.76 %	0.59 %
23X	0.54 %	0.73 %	0.59 %	0.71 %

Figure 2. Distributions of Standard Deviations of the Flood Field Signal



The best result demonstrates mean/maximum standard deviation 0.40% and 0.93%, while worst observed result shows 0.91% and 1.21%, respectively.

MONITORING OF EPID RESPONSE AGAINST WATER-EQUIVALENT DETECTOR

Table 2 shows standard deviations of EPID/detector signal ratios measured over the entire observation period for all beam energies, both linacs, and both reference detectors used.

Table 2. Standard Deviations of EPID/Water-Equivalent Detector Measured Signal Ratio

Beam Energy / Detector Type	Unit A		Unit J	
	Ion Chamber	MatriXX	Ion Chamber	MatriXX
6X	0.26 %	0.27 %	0.56 %	0.23 %
6FFF	0.42 %	0.86 %	0.49 %	0.52 %
10X	0.25 %	0.24 %	0.72 %	0.65 %
10FFF	0.55 %	0.69 %	0.83 %	0.22 %
23X	0.23 %	0.43 %	0.46 %	0.21 %

Figure 4 demonstrates scatter plot of EPID/Ion chamber ratios for two scenarios: the greatest and smallest standard deviation observed (Unit J, 10FFF and Unit A, 23X). Pearson correlation coefficients between EPID and ion chamber measurements are 0.86 and 0.93, respectively.

Figure 4. Normalized EPID / Ion Chamber Responses for Two Beam Energies Showing Greatest and Smallest Scatter

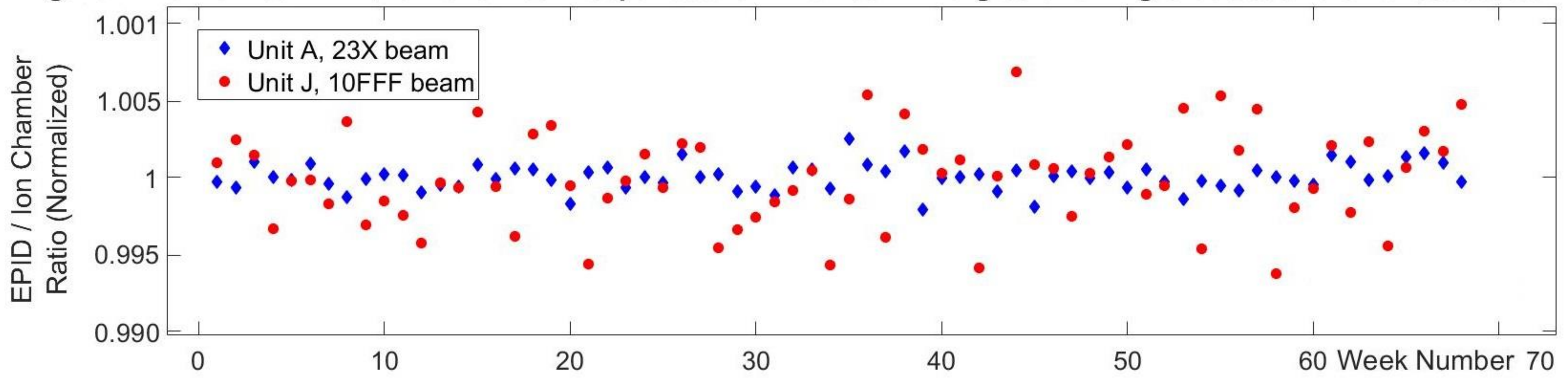
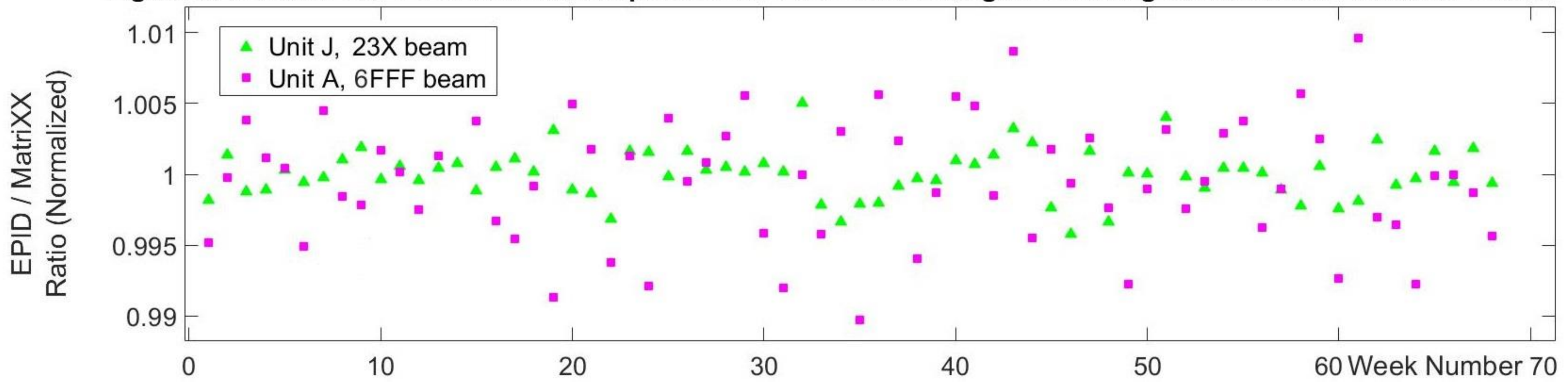


Figure 5 demonstrates scatter plot of EPID/MatriXX ratios for two scenarios: the greatest and smallest standard deviation observed (Unit A, 6FFF and Unit J, 23X). Pearson correlation coefficients between EPID and MatriXX measurements are 0.82 and 0.88, respectively.

Figure 5. Normalized EPID / MatriXX Responses for Two Beam Energies Showing Greatest and Smallest Scatter



All datasets have coefficient of determination R^2 from 0.13% to 0.17% showing no trend present.

CONCLUSIONS

Techniques to monitor long-term dosimetric behavior of EPID were implemented. Both dark and flood calibration fields demonstrate good constancy over a long time period. Dark field measurements show smaller deviations than flood field. Dark field shows greater signal variation in dosimetry mode, while flood field shows greater variation in continuous mode. Pixel sensitivity matrix showed good constancy. EPID response compared to water-equivalent detector measurement also remained constant over the long time period (no significant drift). It was demonstrated that the a-Si 1200 EPID produces stable and reproducible dosimetric performance over a 24-month period.

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