International Journal of Theoretical and Applied Research (IJTAR)
ISSN: 2812-5878

Homepage: https://ijtar.journals.ekb.eg

Original article

Comparison Study of portal dosimetry with PTW 2-D array system for IMRT for specific QA in Breast Cancer patients

Afanan Mahmoud Mohamed [1], Sahar M. Awad[2], Areej E. Mohamed[2], Khaled M. Elshahat[3]

[1]Radiology Department – El Hussein Hospital- Al-Azhar University- Cairo- Egypt
[2]Department of Physics-Faculty of Science- Al-Azhar University- Cairo- Egypt
[3]Clinical Oncology Department - Faculty of Medicine – Al-Azhar University- Cairo- Egypt

ARTICLE INFO

Received 10/07/2023
Revised 03/12/2023
Accepted 11/12/2023

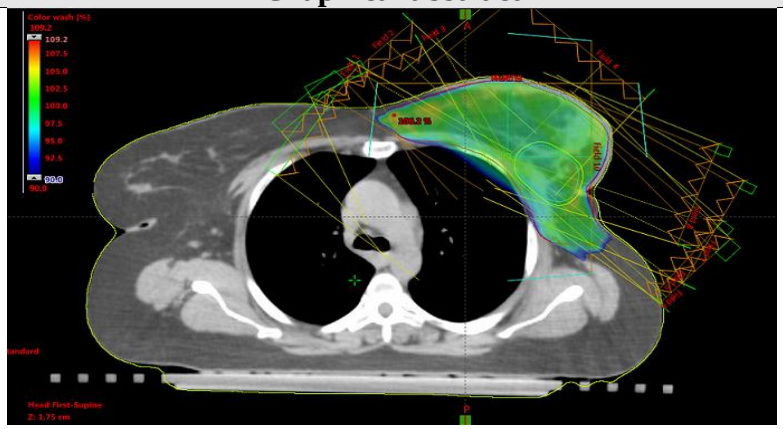
Keywords

Portal dosimetry IMRT (Intensity Modulation Radiation Therapy) Radiotherapy
Breast Cancer
QA (Quality Assurance)
Electronic Portal Imager Device (EPID)

ABSTRACT

The IMRT (Intensity Modulation Radiation Therapy) and rapid arc give uniform desired dose distribution to the target volume with adequate sparing of the nearby critical structures. The portal dosimetry system and 2-D array system are widely used as relative dosimetry detectors, because of their consistency in results, less time consumption, and ease of use. In the current work, twenty cases of dynamic IMRT plans were selected for the patient-specific QA (Quality Assurance) study using portal dosimetry and a 2-D(Two Dimensional) array set square pattern ,spaced 10 mm apart across the entire measurement area using Detectors Number 729 (Planar dose comparison was carried out with gamma criteria of 3% -3 mm (DTA)(Distance To Agreement). For the portal, dosimetry system area gamma, passing the 3%-3mm gamma was chosen. The current study Varian Linac Unique at El Hussein Hospital Electronic Portal Imager Device (EPID) is a flat panel X-ray imager with a large area active matrix readout structure, made up of phosphor or photoconductor. The 2-D array system consists of 1020 parallel plate ion chambers arranged in a 32x32 grid, with an inter-detector spacing of 7.619 mm. Each detector has a diameter of 4.5 mm, a height of 5 mm, and a chamber volume of 0.02 cc**.** IMRT in pre-treatments to help select Pγ%< 1 point and relevant transition criteria to assess the reproducibility of treatment fractions. Compared to a 2D Array system., although the 2D array has limited sampling capabilities. The portal dosimetry soft for portal imager device (EPID) has a good result for breast cancer plan evaluation versus 2D array results and agreement with international publish data, in addition, reduces the time for calibration due to there is no need for extended cable for measurement is compared with a 2D array

Graphical abstract



∗ *Corresponding author*
E-mail address: afnanelhaggar@gmail.com

DOI: 10.21608/IJTAR.2023.203392.1048

Special issue "selected papers from the 2nd International Conference on Basic and Applied Science (2nd IACBAS-2023)"

1. Introduction

Although sophisticated means to calculate and deliver modulated dose distributions have been developed, means to measure the actual dose delivery using 2D (two-Dimensional) arrays, and Electronic Portal Imaging Devices (EPIDs) are often relatively cumbersome. In addition, these detectors are generally used for standard tests in pretreatment conditions to verify the dose map in homogeneous standard phantoms. [1-2], the steep dose gradients associated with IMRT, in vivo verification of dose distribution in multiple therapeutic sections, is prudent to ensure patient safety. Although sophisticated means for calculating and delivering modulated doses have been developed, means to verify their actual distribution using X-ray films, 2D arrays, and electrical portal imaging devices EPIDs are often relatively cumbersome. In addition, these detectors are commonly used for standard tests under pretreatment conditions to verify dosages of primary homogeneous standard specters. EPID appears to be a valuable tool for in vivo quality (Quality assurance internal) assurance purposes [1–4] in particular, to ensure beam centering by visual inspection. However, there is no direct and practical method to check the exact position of the patient, the exact position of the leaves, and the dose measurement during the treatment In some institutions, methods for determining the distribution of the patient-passed port dose have been developed to obtain comparisons between planned and replicated dose distribution in patients [5–7]. Indeed, if the accurate electron density information in the CT scanner is indeed representative of the patient at the treatment site and the dose calculation of the Treatment Planning System (TPS) under the patient is accurate, can compare online portal doses calculated and measured the Field Of View (FOV) of CT (Computed Tomography), to detect uncertainties of doses or alterations in patient focus. Unfortunately, first-generation liquid-filled array (LiFi) ion chambers and camera-based fluorescent EPID soften produce images with poor contrast and limited stability, the latter being due to temperature fluctuations and radiation damage. In addition, the non-linear dose-response and field size-dependent optical photon propagation make them difficult to calibrate and use clinically. The third and newer EPID layer uses amorphous and more efficient silicon

2. Materials and Methods

In the current study Varian 6MVlinear accelerators unique model at El-Hussein hospital (Varian Medical Systems, Palto Alto, CA) UNIQUE Multi-leaves shaping system (80 MLC) implemented with amorphous silicon detectors, a-Si1000 is used. The Varian a-Si EPID consists of 1 mm copper plate, 134 mg/cm2 gadolinium oxysulphide phosphor screen with an active area of 40 cm × 30 cm a-Si arrays. The EPID differs in the spatial resolution of the device us a Si-1000 is 0.391 × 0.391 mm^2. The linear accelerators are connected with Treatment Planning Systems (TPS) (Varian Medical System, Palto Alto, USA version 15.1, algorithm: PDIP-11031)

The PTW 2D array (Dosimetry company - model dosimetry system for relative evaluation and verification for IMRT dose) is equipped with the 2-D array system consisting of a 1020 parallel plate ion chamber arranged in a 32x32 grid, with an inter detector spacing of 7.619 mm. Each detector has a diameter of 4.5 mm, a height 5 mm, and a chamber volume of 0.02 cc. the reference point is located 0.5 cm from the 2D array surface. Spaced 1 cm apart, the 2D array's external dimensions are 30 × 42 × 2.2 cm3, and the surrounding material is polymethyl methacrylate (PMMA). The 2D array system (mass 2.4 kg) consists of the chamber array itself, which also accommodates part of the electronic device, the array interface, and a data acquisition board for the personal computer.

3. Results

Table 1. Pretreatment verification using the model compared to 2D array dose at 10 cm depth.

Case No.	EPID %	2D array %
1	97.85	100
2	98.2	100
3	98.5	99.5
4	99.1	100
5	98.52	100
6	98.13	100
7	97.95	99.8
8	99.2	99.6
9	99.4	100
10	98.95	100
11	99.5	100
12	99.6	99.8
13	98.78	99.6
14	99.6	99.56
15	98.96	99.75
16	98.65	100
17	99.6	100
18	98.95	99.65
19	98.6	99.6
20	98.6	100
Mean (SD)	98.1(1.5)	100(0.0)

- The first step starts with testing the EPID against 2D array and some parameters may be affect on the accuracy of measurement.
- As shown in Fig.1 the dose rate for linear – there is no difference in response of portal imager in compared with the standard tool for calibration 0.6 cc chamber for Dose measured variations in between treatment planning system versus both dosimetry system (portal and 2D array system) for 20 breast cancer patients.

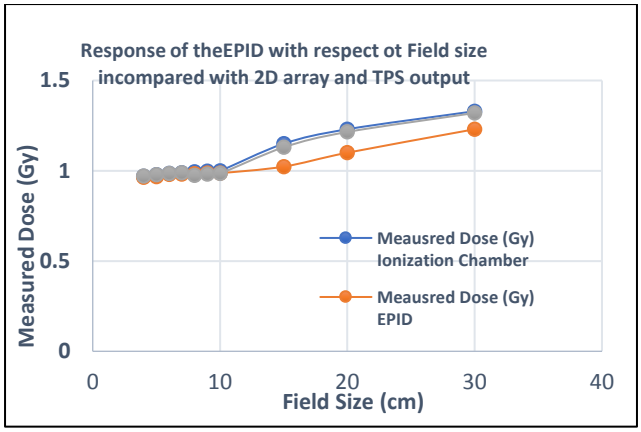


Fig. (1): the response of the EPID output for different field sizes from 3x3 cm to max field size 30x30 cm in compared with 2D array and TPS.

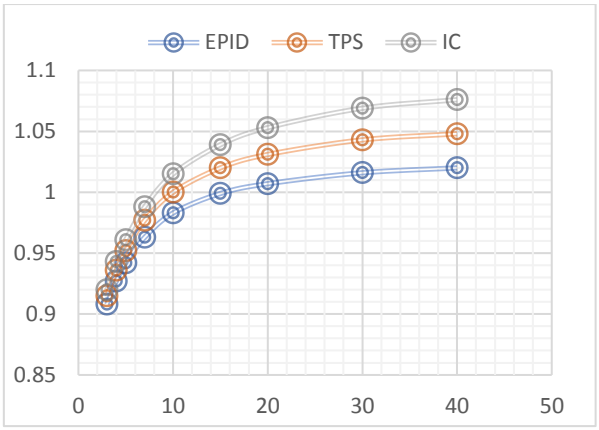


Fig. (2): Different field depends on comparison between EPID, Treatment Planning System, and Ionization Chamber

- As shown in Fig. 2 the comparison for different field sizes between TPS, EPID, and IC minimal variation with no significant values between the date calculated and measurements using IC(Ionization Chamber) and EPID for abolute dose.
- As specified by the manufacturer, the 2D array supplies dose measurements with high reproducibility in a range between 0.2 Gy and 10 Gy and dose rates in a range between 0.5 Gy min^{-1} and 8 Gy min^{-1}, with a resolution of 1 mGy min^{-1} (using a display cycle that can be selected from between 400ms and 999 ms). Comparing these results with those obtained by the dose characterization of 2D array PTW, it is possible to conclude that the PTW 2D array presents minor dose rate dependence as compared to 2% or 3% for *n*-type or *p*-type diodes.[8] However, in a recent paper a comparison of the dosimetric characteristics of the 2D array PTW, the more recent PIX (Pixel ionization chamber prototype) shows that these 2D arrays are good tools for the quality assurance and verification of the IMRT plans in the pre-treatment step.[8-10].
- For data measured for 20 breast cancer patients for both systems, there are now differences in 2D array data as average for all patients with 98.7% ±1.2 pass values for 3DTA /3mm and data for Portal dosimetry system 98.4 %±1.65 passing values for the same criteria of acceptance for verification for all breast cancer cases. there is no significant variation P=0.025 [11].

Breast plan IMRT – using treatment planning system: -

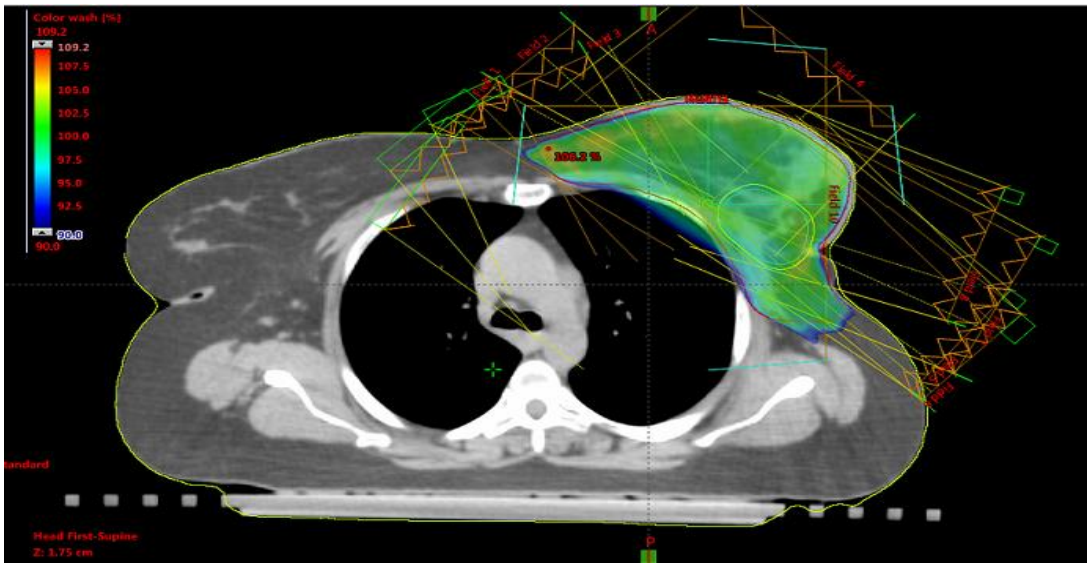
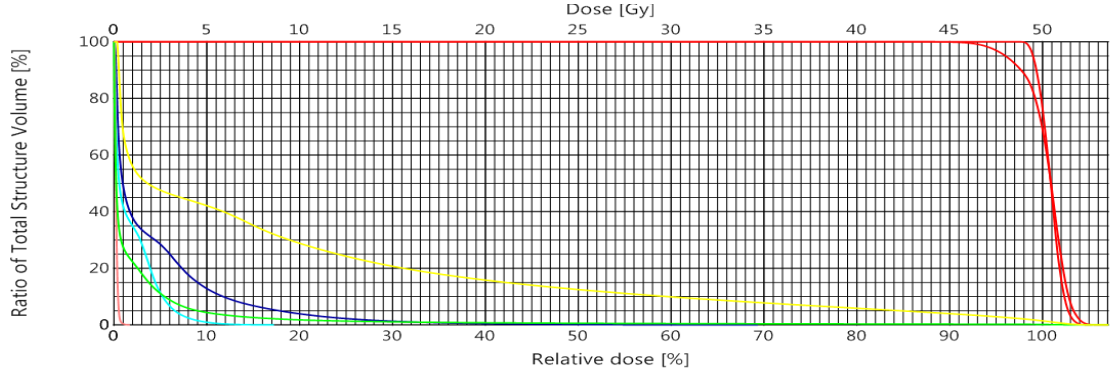


Fig 3. The Axil view for breast IMRT plan and field orientation

Dose Volume Histogram (DVH) for breast IMRT plan:



DVH	Structure	Structure Status	Coverage [%/%]	Volume	Min Dose	Max Dose	Mean Dose	Modal Dose	Median Dose	Std Dev
	GTV	Approved	100.0 / 100.0	16.9 cm³	97.4 %	105.4 %	100.9 %	101.1 %	100.9 %	1.1 %
	PTV	Approved	100.0 / 100.0	40.7 cm³	82.5 %	107.1 %	100.5 %	101.1 %	100.9 %	2.2 %
	Heart	Approved	100.0 / 100.0	359.0 cm³	0.0 %	1.7 %	0.2 %	0.1 %	0.2 %	0.2 %

Portal Dosimetry: -

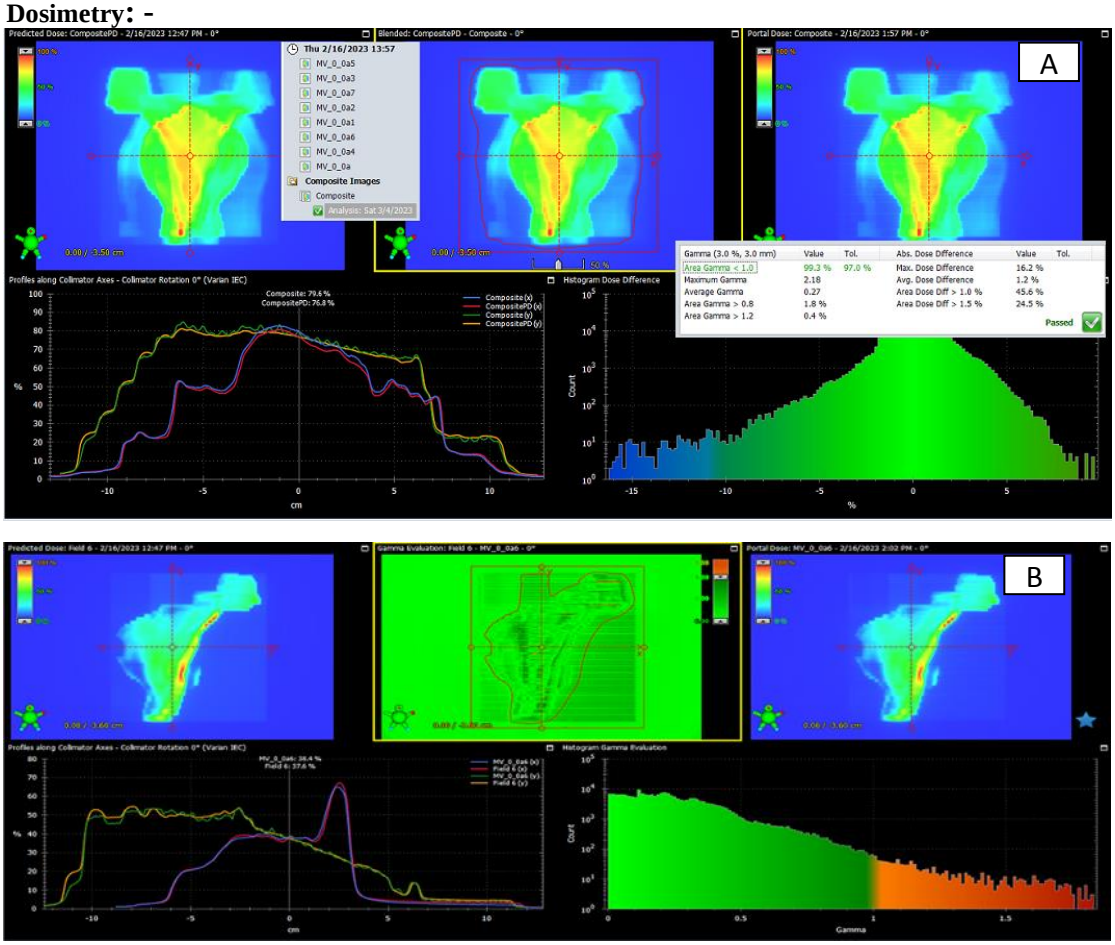


Fig. 4 : the evaluation screen for breast cancer as composite plan for all field summary results A. and for single field result B.

4. Discussions

Advanced technology is needed for dosimetric quality assurance (QA) programmers in complicated radiation treatment plans like IMRT .However, for IMRT, a pre-treatment control of the estimated dosage in standard phantom for each beam is required in addition to a complete program for the QA of the LINAC, the simulator, the TPS, and independent checks of radiation treatment parameters (distances, field size, etc).[12-14]

In many centers, 2D arrays, like the PTW here presented, are used for pretreatment verification dose calculation for the beams chosen for breast cancer patient therapy. However, because to the time-consuming nature of this verification before the treatment, the radiation center operations are needed for 10 or 30 minutes, depending on the number of fields .

The pretreatment verification of the dose calculation for the beams selected for patient therapy is carried out by 2D arrays as the PTW was reported for breast cancer in the current study. However, this verification requires a

lot of work before treatment, which interrupts the activity of the radiotherapy department for 15 min or 30 min, depending on the number of fields. To avoid such interruptions, this verification is not repeated in the following fractions of the therapy. It is the current study that pretreatment verification is a very important method for the evaluation of dose calculation with a Treatment planning system, while it could also be accurate to check the following fractions of the therapy to verify the constancy of the following: [15-17]

(1) The accuracy of dose delivery

(2) Correct patient positioning to verify patients' uncertainties during the treatment sessions.

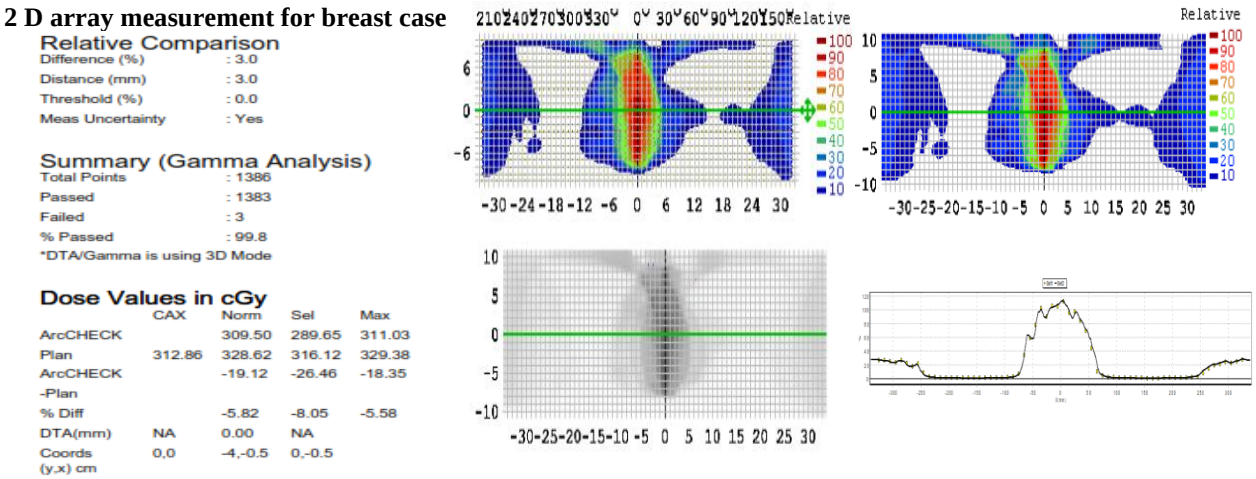


Fig. 5. The data results for the same case using 2 array system

EPIDs are probably the most effective and easy devices for IMRT verification and dosimetry These detectors can provide high-resolution and highly efficient planar dose maps. However, further developments are underway for the deployment of this technique into routine clinical practice.

In the current study, the 2D array dose detectors could be used together with EPIDs for complete *for* QA purposes. The PTW 2D array here examined is a practical detector for radiotherapy verification even if the ion chamber spacing of 1 cm results in a limited sampling of the radiation beam. However, this limitation does not seem to affect its possible use to accurately check several dose points. The dose calibration for the 2D array is stable and easier not more than portal dosimetry. For a small number of MUs (≥10), the IMRT technique a high level of dosimetric accuracy as shown in Fig 4 and 5. Moreover, this array seems to be a water-equivalent detector.[18]

The 2D array was implanted in a TPS for the IMRT portal dose calculation using a slab of water-equivalent material. This way, the software for 2D array was realized to extract from the TPS the maps of portal doses on specific planes in the FOV for Breast plan and more effective than portal dosimetry. In addition, in some studies portal dosimetry is affected by dose rate some results deviation within the limit due to low dose rate and larger FOV for breast cases.[19]

In irradiation of a phantom with IMRT beams and measuring portal doses with a 2D array with high spatial resolution, we have determined that the TPS Eclipse supplies a dose computation with a $P_{\gamma<1}$ > 96% of portal dose points with acceptance criteria of ΔD_{max} = 3. % and δd_{max} = 3 mm. in current comparison between the calculation dose and measured portal dose values by the 2D array. The number of chambers that found a dose calculation within the acceptance criteria and limited is more than 95%. In other words, the good agreement observed between the measured dose profiles obtained in standard phantoms by the 1D array LA48 and the 2D array (ΔD_{max} = 2% and δd_{max} = 2 mm) justifies the 2D array's $P_{\gamma<1}$ > 95%. We think that the discrepancies are due both to the accuracy level of the portal dose calculation as well as the grid (2.5 mm) used the sampling of the dose points between the different portal dose profiles. the 2D array presents a limited sampling capability, it is our opinion that the observation of about 1000 points (200 per beam) is enough for a detailed evaluation of the portal dose reproducibility in many fractions of the therapy.(19) This kind of verification can be carried out during the treatment, positioning the 2D array in a particular jig that can follow the rotation of the portal vision. The effect of 5-mm shifts of the Breast allows one to estimate a decrease of $P_{\gamma<1}$ to 90% of points inside the acceptance criteria of ΔD_{max} = 3% and δd_{max} = 3 mm. This result can be useful for the *verification* QA. (20) Moreover, the procedure allows the observation of an incorrect angular position of the MLCs. Shown a drop of $P_{\gamma<1}$ to 87% when an error of 5° in the rotation of the beam collimators was simulated. [20]

5. Conclusions

-In conclusion, the methods tested here based on IMRT breast irradiation can be used in breast cancer if the dose calculation is within the scanners' field of view. We intend to use it for IMRT in pre-treatments to help select Pvalue%< 1 point and relevant transition criteria to assess the reproducibility of treatment fractions. Compared to a 2D Array system, although the 2D array has limited sampling capabilities, we believe that observation of approximately 1,000 points (200 per beam) is sufficient for a detailed evaluation of portal dose re-

producibility across multiple treatment fractions. This type of verification can be performed during treatment by inserting the 2D crosshair into a special device that can track the rotation of the portal view.

- In current comparison the portal dosimetry soft for portal imager device (EPID) have a good result for breast cancer plan evaluation versus 2D array results and agreement with international publish data. in addition, reduce the time for calibration due to there is no need for extended cable for measurement in compared with 2D array.

References

1. T. Wiezorek, M. Banz Nschwedas, D. Georg and T. G. Wendt, "Dosimetric quality assurance for intensity-modulated radiotherapy feasibility study for a filmless approach," Strahlenther. Oncol., 181(2005) 468-474. https://doi.org/ 10.1007/s00066-005-1381-z.
2. F. Branci Buonamici, L. Marrazzo and S. Russo, "An inter comparison between film dosimetry and diode matrix for IMRT quality assurance," Med. Phys., 34(2007) 1372-1379. https://doi.org/10.1118/1.2713426
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., 32(2005) 3267-3278. https://doi.org/ 10.1118/1.2074227
4. P. Winkler, A. Hefner and D. Georg, "Dose- response characteristics of an amorphous silicon EPID," Med. Phys., 32(2005) 3095-3105. https://doi.org/10.1118/1.2040711
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., 29(2002) 2262-2268. https://doi.org/10.1118/1.1508108.
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., 30(2003) 1618-1627. https://doi.org/10.1118/1.1582469
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., 50(2005) 3361-3373. https://doi.org/10.1088/0031-9155/50/14/012
8. B. V. Elsevier, "Evaluation of a 2D diode array for IMRT quality assurance," Radiother. Oncol., 70(2009) 199-206. https://doi.org/10.1016/j.radonc.2003.10.014.
9. International Atomic Energy Agency-IAEA (2008), Transitioning from 2D radiotherapy to 3D and IMRT radiotherapy, INPRO Manual — Overview of the Methodology. *IAEA* TECDOC No. 1575. IAEA-TECDOC-1575. https://doi.org/978-92-0-104008-4
10. Taylor, A., & Powell, M. E., Intensity-modulated radiotherapy--what is it. Cancer Imaging: the official publication of the International Cancer Imaging Society, 4(2)(2004), 68–73. https://doi.org/ 10.1102/1470-7330.2004.0003
11. Bayouth JE, Wendt D, Morrill SM., MLC quality assurance techniques for IMRT applications. Med Phys. May; 30(5)(2003):743-750. https://doi.org/ 10.1118/1.1564091.
12. 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.,4(2003),40-50. https://doi.org/10.1120/jacmp.v4i1.2540.
13. C. D. Wagter, "The ideal dosimeter for intensity modulated radiation therapy (IMRT): Jr. Phys., 3(2004) 4-8. https://doi.org/ 10.1088/1742-6596/3/1/002.
14. W. V. Elmpt, L. Mcdermott, S. Nijsten, M. wending, et al, "A literature review of electronic portal imaging for radiotherapy dosimetry," Radiother. oncol., 88(2008) 289-309. https://doi.org/ 10.1016/j.radonc.2008.07.008
15. D. Wagner and Hilke Vorwerk,"Two years' experience with quality assurance protocol for patient related Rapid Arc treatment plan verification using a two dimensional ionization chamber array." Radiat Oncol., 6(2011) 21. https://doi.org/ 10.1186/1748-717X-6-21
16. M. Esposito et al., Estimating dose delivery accuracy in stereotactic body radiation therapy: a review of in-vivo measurement methodsRadiother. Oncol,149(2020)158-167. https://doi.org/ 10.1016/j.radonc.2020.05.014
17. Faroni L. Collie L. Gabrielli F. Baldotto C. Moraes F., Role of stereotactic radiation therapy in operable and inoperable early-stage non-small cell lung cancer.Curr Treat Options Oncol.; 23(2022) 1185-1200. https://doi.org/ 10.1007/s11864-022-01002-x
18. Paelinck, L, Vanderstraeten, B, Srivastava, R, Olteanu, L, De Wagter, C., The effect of the table top modeling on calculations and measurements for the Delta4 phantom. ESTRO; 35(2016) S705–S706. https://doi.org/10.1016/S0167-8140(16)32774-8
19. Chandraraj, V, Stathakis, S, Manickam, R, Esquivel, C, Supe, S, Papanikolaou, N., Comparison of four commercial devices for RapidArc and sliding window IMRT QA. J Appl Clin Med Phys; 12 (2)(2011) 338–349. https://doi.org/10.1120/jacmp.v12i2.3367
20. Nelms, B, Zhen, H, Tomé, W A., Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med Phys; 38 (2)(2011) 1037–1044. https://doi.org/10.1118/1.3544657