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Dosimetric study of photon beam characteristics with 2d array and water phantom measurement

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▸ ***Short report***

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ABSTRACT

Background and Objectives: To show whether the 2D-array scanning system can be used as a substitute for the MP3-water phantom, we have used a comparison of beam profiles and the percentage depth doses for both electron beams and the photons, also we have confirmed the validation of the results by CMS XiO treatment planning system. ***Methods:*** Beam data was obtained for MP3-water phantom and 2D-array scanning system for 6 MV and 15 MV photon beam; and 4, 6, 8, 10, 12 and 15 MeV electron beams generated from ONCOR Digital Medical Linear accelerator for (2×2cm^2, 3×3cm^2, 5×5cm^2,10×10cm^2,15×15cm^{2}and 20×20cm^2) at 10cm depth. CMS XiO treatment planning system was utilized for validation of the obtained data. ***Results:*** doses distribution for the two studied systems is compared with uncertainties within the recommended limits. It is found that there's no vital variation in flatness and symmetry obtained from the 2D-Array as compared to the quality MB3-Water Phantom Flatness and symmetry obtained is well at intervals the limit of ±3%. ***Conclusion:*** it is concluded that the 2D-Array-729 is used for the routine measuring of the photon beam profiles as alternative to water phantom.

Keywords: *2D-Array seven29, water phantom, beam profile, flatness, symmetry and penumbra.*

INTRODUCTION

Water phantom scanning systems are utilized to describe and characterize the dose distribution from photon and electron beams in radiation therapy [(1)]. Tank dosimetric information was used for estimation of the dependence of percent-depth-dose (PDD) curves and profiles on parameters like integration time, scanning speed, scanning resolution and directivity [(2)]. Fast scanning speeds may result in dosimetric errors about 5%, necessitating to understanding of scanning speed dependence for varied scanning water tanks [(2, 3)].

2D-Array detectors have the flexibility to supply two dimensional dose distributions from a single exposure, creating the acquisition of knowledge quicker and the investigation of those beam parameters additional comprehensive because the whole radiations space is evaluated [(4, 5)].

Conventional radiation dosimetry includes measuring doses resulting from ionising radiation and modelling the particle interactions within tissues, particles. The most common kinds of indirectly ionizing radiation are photons. Indirectly ionising radiation consists of uncharged particles. The most common kinds of indirectly ionising radiation are photons, interact with matter to produce electrons (and positrons) and these charged particles then produce ionisation along their tracks. The energy transferred from the photon beam to the irradiated material depends on the photon energy, interaction coefficients, atomic number of the material and electron density. The dose to a point in a medium is composed of the primary and scattered components. The primary dose component is composed of deposited energy by emitted photons from the source. The scattered dose component is the result of the scattered radiations from the collimator and materials or irradiated phantom [6].

Medical Physicists in radiation therapy departments are always faced many challenges including the need for precision, a variety of testing methods, data validation, lack of standards and time constraints. Thus, it is essential that the beam data acquired should be of high quality to avoid dosimetric and patient treatment errors, which may subsequently lead to more advanced radiotherapy treatment techniques were then introduced to the field of radiotherapy after the invention of medical linear accelerators. This included three dimensional conformal radiation therapy (3DCRT) and intensity modulated radiation therapy (IMRT) [7].

The aim of this study is to determine whether the 2d-array can be used as a substitute for the water phantom used during linear accelerator set up dose calibration, commissioning and verification measurements. To compare the photon beam dose distributions is measured by the water phantom compared with that which is measured by the 2d-array. We have compared the absolute dose measurements for both systems for all photon beam energies of an Oncor linear accelerator. Also, we have validated the dose distributions by compared the modeled data with both profiler 2d-array scanning system and the water phantom data.

MATERIALS AND METHODS

A high-energy linear accelerator (ONCOR Digital Medical Linear accelerator, SIEMENS, Medical Solution, Inc)) with nominal 6 and 15 MV photon beams has been installed in radiation oncology department in Menia cancer center by the first author. In the present study, Oncor model twin energies 6MV and 15MV was used as a Linear accelerator which is used for treatment of deep sitting tumors and 4, 6, 9, 10, 12, 18 and 21 MeV electron beams for superficial treatment of cancer tumors and alternative malignancies. In order to measure the high-energy Semiflex chamber (0.125 cm^3), ionisation chambers were used, and the Pinpoint chamber (0.015 cm^3) is also utilized for measuring of fields of the 2D Array Seven29 model (PTW, Freiburg, Germany) and small inner diameter 3 metric linear unit.

The gantry was set to be upright position initially to zero degree rotation and then leveled using spirit level to ensure the correct alignment. The water tank and 2D-Array is set to be SSD of 100cm and the moving mechanism is leveled to the cross wire of collimator and phantom axis line [8].

The pressure and temperature were measured for calculation of the correction factor that determines the pressure and temperature effects on the measurements. Different small fields were irradiated by field to measure the absorbed dose for each field.

PTW 729 2D-arrays consists of a plan matrix of 27 ×27 air filled ionisation chambers was used (PTW, Freiburg, Germany).The detector spacing (center to center) is 1 cm [9] and the dimensions of each detector are 0.5 × 0.5 × 0.5 cm^3. Verisoft 4.0 program helps to see the relative in addition as absolute measurements [10].

MP3 – M – water phantom 50cm×50cm×40cm model 9860 (PTW, Freiburg, GmbH) with wall material (thickness) Acrylic (2cm), arm step size resolution is 0.1mm, maximum speed of arm 5cm/sec, tank setup with time 20 min Scan time per field 20 – 40 min from multi-data scanning system [8].

The measurements were performed for the following energies 6MV and 15MV photon beams with different field sizes (2×2cm^2, 3×3cm^2, 5×5cm^2,10×10cm^2,15×15$cm^2$and 20×20cm^2) at 10cm depth.

The radiation field flatness of the beam is defined by the following formula:

$$\text{Flatness } (\%) = D_{max}/D_{min} \times 100\% \qquad (1)$$

Where, D_{max} and D_{min} are the maximum and minimum doses severally among the {area|the world|the realm}. The flatness of the beam depends on the dimensions and form of the mensuration phantom.

Radiation field symmetry is outlined as the quantitative relation of doses at two symmetrical points relative to the central axis of the field.

Symmetry (%)=[D(x,y)]/[D(-x,-y)]×100%. (2)

The beam penumbra was measured as the following formula:

Penumbra =S (SSD + d-SDD)/(SDD) (3)

Where, S: source diameter and SSD: source surface distance.

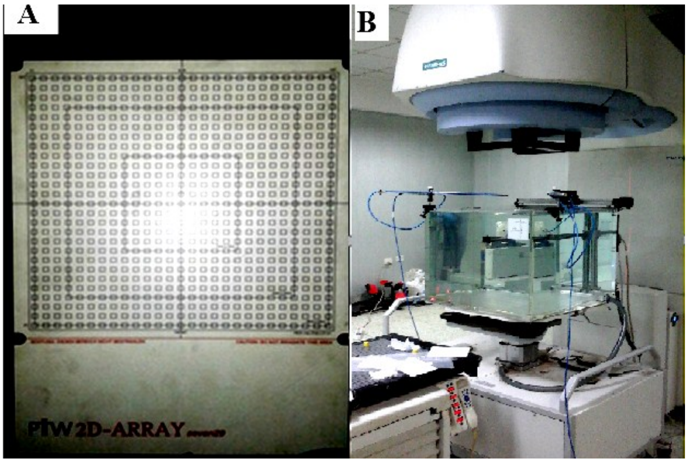

Figure 1. A) 2D-ARRAY-729 and **B)** MP3- M- WATER PHANTOM.

RESULTS

The variations in flatness and symmetry of photon beam 6MV and 15MV energies were obtained from 2D Array-729 and compared with that obtained from the water phantom.

The study of flatness and symmetry showed that the flatness of photon beams were obtained from the 2D Array-729 which is inside the limit of tolerance ± 3% and the symmetry of photon beam are inside the limit of tolerance ± 2%. The measurements were performed for the subsequent energies 6 and 15 MV photon beams with different field sizes (2×2cm^2, 3×3cm^2, 5×5cm^2,10×10cm^2, 15×15cm^2 and 20×20cm^2) at 10cm depth.

From figure (2A) it was evident that the 2D-ARRAY scanning system beam profiles for the 6 MV photon beam measured for different field sizes at different depths followed the same trend as for the water phantom beam profiles, except that the profiles are prolonged on the 2DARRAY scanning system at the wash-out region as compared to the water phantom. This result could be due to a number of ion chambers receiving the signal in 2DARRAY scanning system outside the field region.

Figure (2B) shows that the 2D-ARRAY scanning system beam profiles for the 15 MV photon beam measured for different field sizes at different depths followed the same trend as for the water phantom beam profiles.

Table 1 shows the different between 2D Array Detectors and Water phantom in Symmetry 0.14% , Flatness 0.88% , Penumbra right 0.0183% and Penumbra left 0.0181% as shown in figure 4 (a, b).

Table 1 also shows the different between 2D Array Detectors and Water phantom in Symmetry 0.6%, Flatness 1.93%, Penumbra right 0.83% and Penumbra left 0.0105% as shown in figure 3 (a, b), the measurements analyses 6 MV photon beam Profiles with 2D-Array Detectors and Water phantom at field size 10×10 cm^2 and depth 10 cm.

Figure 3 Shows dose profile characteristics (Symmetry, Flatness, Penumbra right and Penumbra left) and the measurements analyses

6MV photon Beam Profiles with 2D Array Detectors and Water phantom at field size 10×10 cm^2 and depth 10 cm.

Figure 4 Shows dose profile characteristics (Symmetry, Flatness, Penumbra right and Penumbra left) of Water phantom and 2D-Array, The measurements analyses 15MV photon Beam Profiles with 2D- Array Detectors and Water phantom at field size 10×10 cm^2 and depth 10 cm.

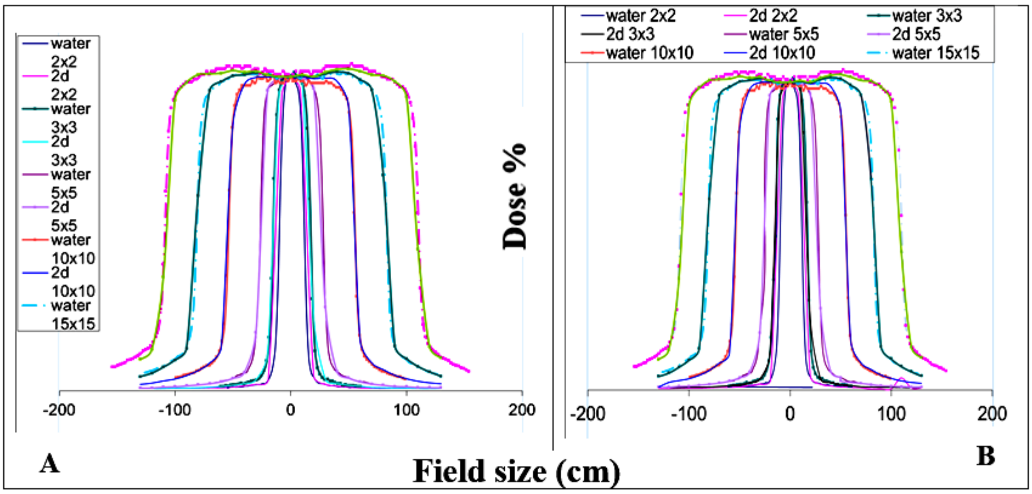

Figure 2. A) Comparison of photon beam profiles,. MB3 -water phantom and profiler 2D-Array scanning system for 6 MV. **B)** Comparison of photon beam profiles, MB3 -water phantom and profiler 2D-Array scanning system for 15 MV.

Table 1. The measurements analyses 6MV and 15 MV photon Beam Profiles with 2D Array Detectors and Water phantom at field size 10×10cm2 and depth 10cm.

Detectors	Symmetry (%)		Flatness (%)		Pen. Right (mm)		Pen. Left (mm)	
	6MV	15 MV	6MV	15 MV	6MV	15 MV	6MV	15 MV
Water phantom	0.45	0.34	2.37	2.05	6.22	7.51	6.68	7.81
2D array	0.59	0.94	3.25	3.98	8.05	8.34	8.49	8.86

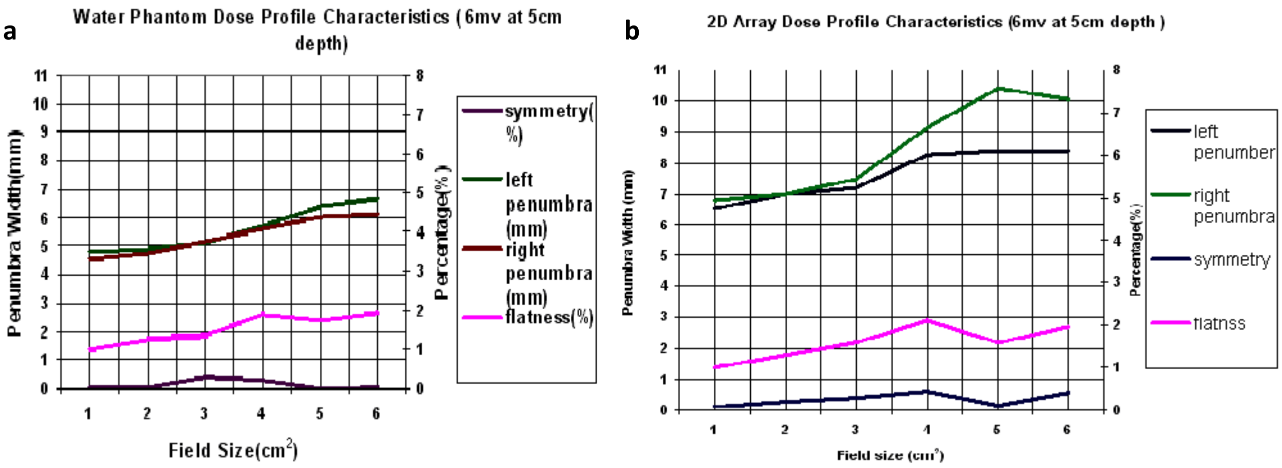

Figure 3. (a) Water Phantom Dose Profile (6mv at 5cm depth), **(b)** 2D-Array Dose Profile (6mv at 5cm depth).

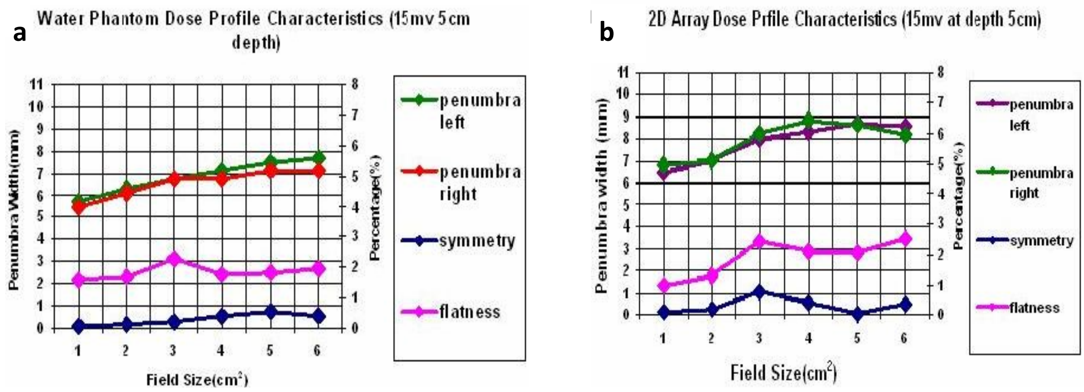

Figure 4. (a) Water phantom Dose profile (15mv at 5cm depth), **(b)** 2D-Array Dose profile (15mv at 5cm depth).

DISCUSSION

The results revealed that the flatness and symmetry of photon beams obtained from the 2d Array-729 are inside the limit of tolerance ±3% and ±2%, respectively. Profiles can be measured by means that of ionization chambers, solid state detectors or radiographic films [11, 12].

The results of The measurements analyses of 6MV photon Beam Profiles with 2D Array detectors and MP3-water phantom (at field size 10×10cm2 and depth 10cm) and The measurements analyses of 15MV photon Beam Profiles with 2D-Array detectors and water phantom (Table 1 and 2) were well within the recommended limit of ± 3 % in 6MV and 15MV photon beam [13].

Moji and Sithole (2013) Compared the measured photon and electron beam dose distributions between 3D Water Phantom And Profiler 2 scanning systems, the study revealed that the profiler 2 scanning system can be used as a substitute for the 3D-water phantom beam data acquisitions during linear accelerator commissioning wich is come at line with the present study [14].

Figures 3 a & b showed that the two systems (2D-Array and MP3-water phantom) beam profiles for the 6 MV (fig. 3a) and 15 MV in figure 3b photon beams were compared very well within the recommended limits of 2 mm (± 2 %) generally, except for the 20 × 20 cm2 field size beam profiles for the 15 MV photon beam where there was a slightly high difference in the wash-out area. This may be due to the inherent 0.9 cm build-up of Perspex in the 2D-Array which has the density close to that of water but not the same.

Lee *et al.* (2008) fabricated a fiber-optic radiation sensor with an organic scintillator for measuring the high-energy photon beam generated from a clinical linear accelerator, and a 2D fiber-optic sensor array for measuring high -resolution and the real-time dose distributions for small field radiotherapy dosimetry. Scintillating lights generated from organic sensor probes embedded and arrayed in the water phantom were guided by 10 m plastic optical fibers to the light-measuring device. 2D photon beam distributions in a water phantom were measured for photon beams with different field sizes and energies, the percent depth dose curves for 6 and 15 MV photon beams were obtained, the results revealed that the developed 2D fiber-optic sensor array has many advantages over conventional dosimeters in radiotherapy [15].

CONCLUSIONS

It is concluded that there is no significant variation in Flatness and symmetry which is obtained from the 2D Array-729 as we compared with the Water phantom. There were very slight variations in the penumbra for quantities energy 6MV and 15MV with the symmetry of the radiation beams were within the tolerance limits. The 2D-Array is a dosimetrically accurate and useful device for the profile measurements. Also, the 2D array-729 can be used as an alternative device to measure the photon beam profile and it is easy to use for routine measurement of daily radiotherapy QA and plan verification. It is recommended for the future studies to investigate the limitations associated with 2D-Array scanning system when we used during commissioning measurements of a linear accelerator. Limitations such as field size (maximum field size of 20 × 30 cm^2 at SSD = 100 cm), Perspex slabs number to be used on the 2D-Array scanning system and diagonal profile measurements.

Conflicts of interest: *Declared none.*

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