RESEARCH ARTICLE

Dosimetry evaluation of photon beam profile characteristics for different treatment parameters of quality assurance

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Abstract

Objective: To compare beam profiles of MatriXX scanning system and water phantom for different treatment parameters.

Method: The cross-sectional study was conducted at Al-Amal National Hospital for Cancer Treatment, Baghdad, Iraq, from November 2020 to March 2021. Beam data for 6MV and 10MV photon beams generated from the linear accelerator was utilised at field sizes 20×20cm^2, 15×15 cm^2, 10×10cm^2 and 5×5cm^2 at depth 10 and source-to-skin distance 100cm. Data was obtained for both water phantom and MatriXX system. The dose distribution for the two systems were compared. Data was analysed using SPSS 24.

Results: The 32 measures taken were all related to symmetry and flatness. Flatness data indicated that all measurements were within tolerance except for cross line plane variations in 10x10cm^2 field size with 6MV energy (-3.81%) and 5x5cm^2 field size with 10MV energy (-3.01).Symmetry data revealed all measurement differences were within tolerance.

Conclusion: MatriXX system could also be used for routine photon profile measurements as a substitute for water phantom.

Key Words: Water, Photons, Phantoms, Imaging.

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Introduction

Radiation therapy is one of the important components of cancer treatment that involves utilising high-energy radiation to kill or change the genes of cancerous cells, causing them to stop growing. As the energy beams travel through the body to reach the cancer cells, passing through the tumour before ultimately departing the body, they effect even the healthy cells along their journey[1,2]. The goal of radiotherapy is to administer enough radiation to kill the tumour cells while keeping the radiation energy low enough to stay away from the adjacent tissues[3,4].

Medical physicists working in radiation therapy departments encounter a variety of obstacles, like precision challenges, a wide range of assessment methodologies, a lack of standards, data validation and tight deadlines. Also, it is critical that the acquired beam data is of high quality in order to minimise errors in dosimetry and patient treatment, which could result in a poor radiation outcome [5].

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The photon beam is the most often utilised radiation therapy technique. The assessment of energy absorbed in tissues is crucial to the biological impact of radiation. Its goal is to examine the depth dosage characteristics of X-ray beams of various energies in order to improve treatment planning efficiency [6]. The purpose of a linear accelerator quality assurance (QA) programme is to ensure that the machine characteristics do not vary substantially from respective reference values obtained at the time of approval and commissioning[7]. In radiation therapy, the dosage distribution of photon and electron beams is identified and evaluated using water phantom devices[8].

Because the entire radiation space is assessed, MatriXX two-dimensional (2D) array detectors may provide 2D dose distribution from single exposure, making information acquirement faster, and investigation of those beam parameters more comprehensive [9,10]. The key parameters that define the quality of a linear accelerators photon beam are flatness and symmetry. The physical characteristics of treatment administration are unquestionably important in ensuring the quality of routine clinical radiation practice and, consequently, the treatment outcome[11].

The current study was planned to examine if MatriXX 2D array can be utilised for quality assurance of linear accelerator instead of the water phantom.

Materials and Methods

The cross-sectional study was conducted at Al-Amal National Hospital for Cancer Treatment, Baghdad, Iraq, from November 2020 to March 2021. The linear accelerator model employed was Infinity (Elekta, Sweden), which generates photon beams of 6MV and 10MV for deep-seated cancers, as well as electron beams with energies of 4, 6, 8, 10, 12 and 15MeV for superficial therapy of cancer tumours and other malignancies. The multi-data scanning system water phantom (Model 90592, IBA Dosimetry, Germany) used was a large motorised phantom with a detector moving range of up to 60cm that allowed for total scatter contribution for a 40x40cm^2 field size data. The system can scan cross-plane and in-plane beam data as well as diagonal and in-depth (z) direction. In order for beam scanning to be performed, the water phantom must be filled to a depth of 30cm. MatriXX (IBA dosimetry, Germany) is a 2D detector designed for megavoltage dosimetry. A 1020-detector pixel ionisation chamber array is used. The detectors are 0.76cm apart and cover 23. ×23.6cm^2 in total. Each ion chamber is a vented parallel plate chamber with diameter of 0.45cm, height of 0.5cm, and a sensitive volume of 0.08cm3. Measurements were carried out for the energies of 6MV and 10MV photon beams with varying field sizes, like 20×20cm^2, 15×15cm^2, 10×10 cm^2 and 5×5cm^2, at the depth 10cm and source-to-skin distance (SSD) of 100cm.

Photon beams were assessed with 6MV and 10MV energies with similar field sizes at the depth of 10cm. Flatness and symmetry studies revealed that flatness of photon beams derived from MatriXX was within the tolerance limits of +/-3% and photon beams symmetry was within the tolerance limits of +/-5%.

The flatness was evaluated by finding the maximum (Dmax) and minimum (Dmin) dose point values on the beam profile within the central 80% of the beam width. Typically, the symmetry is calculated at Dmax, which is the most sensitive depth to evaluate this parameter of beam uniformity.

The flatness and symmetry of the beam's radiation field were evaluated using the following equations[12]:

$$\text{Flatness (\%)} = \frac{Dmax}{Dmin}\ 100\%$$

$$\text{Symmetry} = \frac{area\ left - area\ right}{area\ left + area\ right} \times 100\%$$

Data was analysed using SPSS 24. Data was presented as percentages, and the difference between the two systems was calculated. The tolerance of all readings was ±3 as per the International Electrotechnical Commission (IEC) guidelines[12].

Results

Of the 32 measurements obtained, 16(50%) each were for flatness and symmetry.

Flatness data showed that all the differences in measurement were within the tolerance limit except in crossline plane 10×10cm^2 field size with 6MV energy (-3.81%) and 5×5cm^2 field size with 10MV energy (-3.01) (Table 1).

Table-1: Flatness measurements comparison between water phantom and MatriXX systems.

Field size (cm)	Inline plane flatness (%) at 6 MV energy			
	Water Phantom	MatriXX	Difference	Tolerance
5 cm x 5 cm	104.70%	103.22%	-1.48%	± 3 %
10 cm x 10 cm	103.20%	105.45%	2.25%	± 3 %
15 cm x 15 cm	103.20%	105.63%	2.43%	± 3 %
20 cm x 20 cm	103.70%	105.54%	1.84%	± 3 %
Field size (cm)	**Crossline plane flatness (%) at 6 MV energy**			
	Water Phantom	MatriXX	Difference	Tolerance
5 cm x 5 cm	104.80%	104.80%	0.00%	± 3 %
10 cm x 10 cm	103.20%	107.01%	-3.81%	± 3 %
15 cm x 15 cm	103.10%	105.36%	-2.26%	± 3 %
20 cm x 20 cm	102.50%	104.10%	-1.60%	± 3 %
Field size (cm)	**Inline plane flatness (%) at 10 MV energy**			
	Water Phantom	MatriXX	Difference	Tolerance
5 cm x 5 cm	101.50%	103.41%	-1.91%	± 3 %
10 cm x 10 cm	104.30%	106.48%	-2.18%	± 3 %
15 cm x 15 cm	104.50%	105.86%	-1.36%	± 3 %
20 cm x 20 cm	105.30%	105.80%	-0.50%	± 3 %
Field size (cm)	**Crossline plane flatness (%) at 10 MV energy**			
	Water Phantom	MatriXX	Difference	Tolerance
5 cm x 5 cm	102.00%	105.01%	-3.01%	± 3 %
10 cm x 10 cm	104.00%	106.53%	-2.53%	± 3 %
15 cm x 15 cm	103.40%	104.06%	-0.66%	± 3 %
20 cm x 20 cm	103.60%	103.82%	-0.22%	± 3 %

Symmetry data showed that all the differences in measurement were within the tolerance limit (Table 2).

Table-2: Symmetry measurements between the study groups..

Field size (cm)	Inline plane flatness (%) at 6 MV energy			
	Water Phantom	MatriXX	Difference	Tolerance
5 cm x 5 cm	103.50%	100.51%	2.99%	± 5 %
10 cm x 10 cm	100.90%	100.87%	0.03%	± 5 %
15 cm x 15 cm	101.60%	101.06%	0.54%	± 5 %
20 cm x 20 cm	101.90%	101.90%	0.00%	± 5 %
Field size (cm)	**Crossline plane flatness (%) at 6 MV energy**			
	Water Phantom	**MatriXX**	**Difference**	**Tolerance**
5 cm x 5 cm	103.40%	101.81%	1.59%	± 5 %
10 cm x 10 cm	100.90%	103.13%	-2.23%	± 5 %
15 cm x 15 cm	100.90%	101.65%	-0.75%	± 5 %
20 cm x 20 cm	101.10%	100.90%	0.20%	± 5 %
Field size (cm)	**Inline plane flatness (%) at 10 MV energy**			
	Water Phantom	**MatriXX**	**Difference**	**Tolerance**
5 cm x 5 cm	101.40%	101.14%	0.26%	± 5 %
10 cm x 10 cm	102.90%	102.49%	0.41%	± 5 %
15 cm x 15 cm	103.20%	102.79%	0.41%	± 5 %
20 cm x 20 cm	102.80%	102.95%	-0.15%	± 5 %
Field size (cm)	**Crossline plane flatness (%) at 10 MV energy**			
	Water Phantom	**MatriXX**	**Difference**	**Tolerance**
5 cm x 5 cm	101.40%	102.06%	-0.66%	± 5 %
10 cm x 10 cm	102.30%	102.35%	-0.05%	± 5 %
15 cm x 15 cm	101.00%	100.73%	0.27%	± 5 %
20 cm x 20 cm	100.90%	100.55%	0.35%	± 5 %

Discussion

MatriXX and water phantom beam profile flatness for 6MV and 10MV photon beams compared well with the recommended 3% limit except for the field size 10×10cm^2 crossline for 6MV where there was slight difference from the limits. This could be due to the inherent build-up in MatriXX, (0.9cm build-up), which has a density similar, but not identical to water.

The current results showed agreement with Moji K M. et al[10], who reported similar inline and crossline flatness data.

In terms of symmetry, MatriXX data was well within the limit for inline and crossline planes compared to the quality of water phantom symmetry attained for 6MV and 10MV. The findings were consistent with those reported by Hassan S., et al.,[11].

The establishment of an appropriate standard for beam profile measurements is problematic. On the other hand, beam symmetry is easily defined. However, the flatness of the beam depends on the dimensions and shape of the measurement phantom. At the time of commissioning an accelerator, it is essential to select a beam profile that suits the accelerator's specification. Subsequently, it is important to ensure that the profile did not change significantly afterward[13,14].

MatriXX is easy to set up on the couch of the linear accelerator. Unlike the water phantom, MatriXX works without scanning movement because it consists of an array detector having 1020 stationary ion chambers with 7.62mm distance from centre to centre. However, MatriXX needs onsite ion chamber recalibration every 3-6 months.

Conclusion

MatriXX could be utilised in place of a water phantom to assess the quality assurance of linear accelerator.

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