RESEARCH ARTICLE

Use the external radiotherapy StarTrack detector to study the electron beam profile

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Abstract

Objective: To assess the electron beam dose verification, and to investigate the dependability and stability of the Startrack two-dimensional array.

Method: The is cross-secional study was conducted from January to April 2021 at the Baghdad Centre for Radiotherapy and Nuclear Medicine, Baghdad Medical City, Baghdad, Iraq. Quality assurance measurements were made using a StarTrack two-dimensional detector on an electron beam with an energy of 12MeV at 1.5cm depth for field sizes 6cm×6cm and 14cm×14cm. The detector was positioned 100cm from the source to the surface of the linear accelerator infinity. Testing was done using the International Electrotechnical Commissioning protocol.

Results: There was a significant difference between field sizes 6cmx6cm and 14cmx14cm (-4.97±0.83, -2.01±0.68, respectively) ($p<0.05$). The beam profile measurements of penumbra, flatness and symmetry were within limits ±2 cm, and ±2 cm, 2%, respectively. The percentage of output dose curve against distance showed instability in crossline for 6cm x 6cm and 14cm x 14cm field size.

Conclusion: The output dose was found to be above the tolerance level, and should be corrected before patient treatment for 12MeV energy electron beam therapy.

Key Words: Electrons, Nuclear Medicine, Radiotherapy,

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Introduction

Quality assurance (QA) is the software used to monitor and maintain a programme's specified level of quality[1-5]. A quality improvement policy is essentially a set of policies and practices for assuring the highest possible level of radiation oncology patient care [6-8].

The Startrack 2D array detector contains 453 vented pixel ionisation chambers with automated temperature (t) and pressure (p) changes [k(t,p)]. It utilises Pixel Ionisation Chamber (PIC) technology with a 5mm main axis detector spacing and 7mm diagonal detector spacing of 56cmx6cmx32cm (width)[9]. The usual measurement of the radiation beams, whether electron or photon, is the penumbra, flatness and symmetry. These measurements are also called beam profile (BP). The physical penumbra refers to the penumbra measured in the dosage profile. The distance between the places at which the 20% and 80% isodose curves intersect the X-axis is taken as maximum dose (Dmax)[10].

Flatness and symmetry refer to the amount of modification permitted in radiotherapy over the target dose to get the prescribed dosage in a volume at all places within the range of tolerances. According to International Electrotechnical Commission (IEC) regulations, the beam's flatness and symmetry are specified, and the Dmax distance between the 90% dosage and the edge of the geometrical field must be 10mm along the principal axis at a water depth of 10cm [11]. The formula that determines the flatness of the beam where Dmax and minimum dose (Dmin) are the maximum and minimum doses, respectively, within the area[12] is:

$$\text{Flatness } \% = \frac{\text{Dmax}}{\text{D min}} ?? 100\% \ldots.(1)$$

The symmetry of the radiation field is defined as the difference in dosage between two places situated symmetrically from the central axis and should be <3% [13].

$$\text{Symmetry } \% = \frac{\text{D x,y}}{\text{D - x,- y}} \text{ x } 100\% \ldots\ldots(2)$$

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Sabbar et al.[10] studied the QA beam profile for electron beam therapy using a linear accelerator for 4 types of energies (6MeV, 9MeV, 12 MeV, 15MeV) through a StarTrack two-diemensional (2D) array for 16 weeks to test the performance and stability of StarTrack. They determined that the StarTrack 2D array detector performed well throughout the QA process. The detetctors were simple to install, but provided information regarding the beam's temporal stability, making them well-suited for beam steering mounting.

The current study was planned to assess the electron beam dose verification and to investigate the dependability and stability of the Startrack 2D array.

Materials and Methods

This cross-sectional study was conducted from January to April 2021 at the Baghdad Centre for Radiotherapy and Nuclear Medicine at Baghdad Medical City, Baghdad, Iraq. Approval was obtained from the ethics review committee of the College of Medicine, Mustansiriyah University, Baghdad.

The study used Infinity Linac (Elekta Incorporation, Atlanta, Georgia, United States). The electron beam has an energy of 12MeV with field sizes 6cmx6cm and 14cmx14cm, and quality control (QC) is performed using a StarTrack 2D array detector. The depth of 1.5cm was determined using poly-methyl-methacrylate (PMMA) perspex. Superficial therapy on the patient's skin was performed, and the machine's diaphragm was frequently outfitted with an applier or cone. The IEC standard was used for QC testing[11].

The guidelines for the electron beam used in the radiotherapy field were in line with the International Atomic Energy Agency (IAEA) Technical Report Series (TRS)-398)[14] and the American Association of Physicists in Medicine (AAPM) Task Group (TG)-142)[15]. The beam profile measurements are one of the most significant QC tests. Profile measures, such as penumbra, flatness at 80% of the isodose line, and symmetry were all included in the study. Beam profiles are subject to the regulations set out by the IEC911). Any fluctuation in the penumbra measurements less than +/-0.20cm is considered acceptable. The average penumbra value was calculated by adding together the percentages of the left and right sides of each profile. There should not be more than a 1cm or 10mm discrepancy between flatness readings, and a 3% discrepancy between symmetry readings or the deviation for electron beams[16].

The electron beam energy used was 12MeV at a field size of 6cmx6cm and 14cmx14cm for 5 weeks to measure the dependability of the therapy.

Results

The dose difference was acceptable for no more than ± 2 centigrade (cGy). There was a significant difference in output dose between the studied field sizes, with the output doses at 6cmx6cm field size being higher than those at 14cmx14cm ($p<0.05$). All the doses exceeded the tolerance level except the dose in the first week with a 14cmx14cm field size which was within the accepted value (Table 1).

Table-1: Output dose measurements for 5 weeks.

	6 cm x 6 cm		14 cm x 14 cm	
	Output dose (cGy)	**Difference**	**Output dose (cGy)**	**Difference**
1st week	104	-4	100.89	-0.89
2nd week	104.89	-4.89	102.1	-2.1
3rd week	104.64	-4.64	102.18	-2.18
4th week	105.08	-5.08	102.14	-2.14
5th week	106.28	-6.28	102.78	-2.78
Mean ± SD	104.97 ± 0.83	-4.97 ± 0.83	102.01 ± 0.68	-2.01 ± 0.68
p-value		*<0.00001*		

cGy: Centigray, SD: Standard deviation.

All the calculated results were within the range of acceptability (Table 2). StarTrack 2D's distance-versus-percentage plot of output dosage profiles for the field sizes of 6cmx6cm showed that the inline results were stable and similar in all weeks, while there was a small change in the apex of the lines for crossline (Figure A-B).

Field size 14cmx14cm showed a wide apex due to a wider window, and the change in crossline was more than the inline curves, especially on the right side of the apex (Figure C-D).

Discussion

The 2D array detector verification devices are now used for patient-specific QA. Poor resolution detectors and the time it takes to connect the detectors and phantom to an external computer system running analytical software are only two of the numerous problems with employing a 2D array system. When comparing portal dosimetry system results to 2D array detector system results, the portal dosimetry system values were found to be more reliable [17].

The current study performed a dose verification checkup and found that the mean dose was higher than 100cGy for both field sizes, especially for 6cmx6cm field size. The difference in output dose was -4.97±0.83 for 6cmx6cm and -2.01±0.68 for 14cmx14cm over 5 weeks, which is not

Table 2: The dose profile.

Inline 6 cm x 6 cm								
	Penumbra Left (cm)	**Diff.**	**Penumbra Right (cm)**	**Diff.**	**Flatness 80 (cm)**	**Diff.**	**Symmetry (%)**	**Diff.**
Reference	**0.97**		**1.01**		**0.39**		**100.09**	
1st week	0.95	0.02	0.98	0.03	0.37	0.02	100.14	-0.05
2nd week	0.98	-0.01	0.98	0.03	0.38	0.01	100.1	-0.01
3rd week	1	-0.03	1	0.01	0.38	0.01	100.19	-0.1
4th week	0.97	0	0.98	0.03	0.37	0.02	100.14	-0.05
5th week	0.96	0.01	1.01	0	0.4	-0.01	100.03	0.06
Crossline 6 cm x 6 cm								
	Penumbra Left (cm)	**Diff.**	**Penumbra Right (cm)**	**Diff.**	**Flatness 80 (cm)**	**Diff.**	**Symmetry (%)**	**Diff.**
Reference	**1.03**		**0.94**		**0.42**		**101.14**	
1st week	0.98	0.05	0.96	-0.02	0.4	0.02	101.57	-0.43
2nd week	0.96	0.07	1.01	-0.07	0.38	0.04	101.5	-0.36
3rd week	0.98	0.05	1.01	-0.07	0.38	0.04	101.13	0.01
4th week	0.99	0.04	0.96	-0.02	0.39	0.03	101.53	-0.39
5th week	1	0.03	0.98	-0.04	0.4	0.02	101.45	-0.31
Inline 14 cm x 14 cm								
	Penumbra Left (cm)	**Diff.**	**Penumbra Right (cm)**	**Diff.**	**Flatness 80 (cm)**	**Diff.**	**Symmetry (%)**	**Diff.**
Reference	**1.05**		**0.96**		**0.2**		**101.57**	
1st week	1.04	0.01	0.91	0.05	0.23	-0.03	102.14	-0.57
2nd week	1.06	-0.01	0.94	0.02	0.21	-0.01	102.05	-0.48
3rd week	1.07	-0.02	0.93	0.03	0.24	-0.04	102.08	-0.51
4th week	1.04	0.01	0.91	0.05	0.22	-0.02	102.07	-0.5
5th week	1.06	-0.01	0.93	0.03	0.24	-0.04	102.08	-0.51
Crossline 14 cm x 14 cm								
	Penumbra Left (cm)	**Diff.**	**Penumbra Right (cm)**	**Diff.**	**Flatness 80 (cm)**	**Diff.**	**Symmetry (%)**	**Diff.**
Reference	**0.97**		**1**		**0.13**		**100.91**	
1st week	0.95	0.02	0.96	0.04	0.1	0.03	102.03	-1.12
2nd week	1.01	-0.04	0.94	0.06	0.13	0	102.44	-1.53
3rd week	1.01	-0.04	0.95	0.05	0.12	0.01	101.3	-0.39
4th week	0.96	0.01	0.95	0.05	0.09	0.04	103.21	-2.3
5th week	1.01	-0.04	0.96	0.04	0.13	0	101.78	-0.87

safe for the patients. The difference in results was highly significant between the field sizes ($p<0.05$).

The homogeneity of the electron beam may be properly characterised by defining a configuration based on fundamental flatness and symmetry criteria at a reference depth[17]. Any change in the beam profile indicates a problem with the linear accelerator (LINAC) configuration, and it is not suitable to use the same criterion as commissioning. So, the profile should not deviate from its shape by >2%. The beam asymmetry affects beam steering. Only measurements taken within the flattened

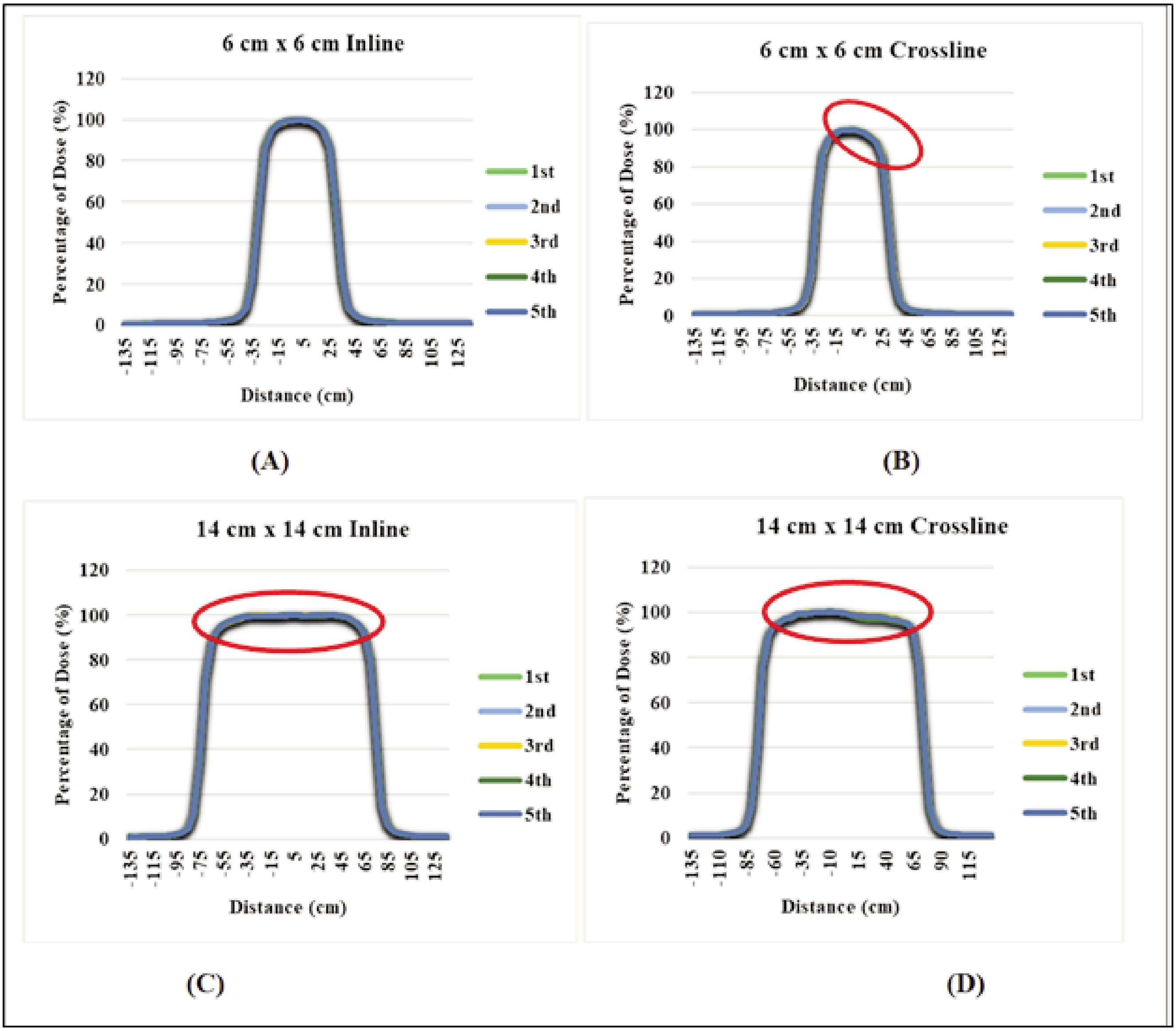

Figure: The dose during 5 weeks at
(A) 6cm x 6cm for inline, (B) 6cm x 6cm for crossline (C) 14cm x 14cm for inline, and (D) 14cm x 14cm for crossline.

region have been recommended for use to determine flatness and symmetry[16].

Symmetry refers to the distribution of dose along the beamline, whereas flatness refers to the average to the lowest dose in each beam. A 3% asymmetry is allowed by the IEC[16]. However, a modern accelerator would enable 100% beam symmetry[18]. Even then, a quick check only needs 3% measurement accuracy. The current results in this regard agreed with Sabbar et al.[10]

For open-field simulations of the penumbra, the profile requirements are dependent on the treatment planning system (TPS) (6cmx6cm and 14cmx14cm). Irradiating healthy tissues may happen, for instance, if the penumbra values were to be greatly increased[19].

Patatoukas et al.[18] investigated the relationship between energy and penumbra. They included different energies and found that the mean percentage difference decreased considerably when the beam energy increased. They use a variety of ionizing chamber detectors for QA measurements, while the current study employed a StarTrack 2D array with IEC standards. The penumbra values in the current study did not surpass the +/-0.20cm value, indicating that the results obtained with the StarTrack 2D array were stable and reliable.

Pathak et al.[17] also employed multiple tools, field sizes and energy parameters.

According to a study[22], the 2D array delivers superior overall accuracy to the single ionization chamber. The dosage calibration for the 2D array is also simple and consistent.

However, the 2D array system has several limitations, including limited detection resolution, lengthy setup times, the use of a phantom, and the necessity to connect to a separate computer system running analysis software.

Conclusion

The output dose alone and the 2D array distance above the tolerance should be corrected before patient treatment, while the beam profile was found to be stable for 12MeV of electron beam therapy. Weekly checkups should be performed to acquire accurate results.

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