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Physical characteristics of photon beam from a CLINAC-DBX single energy accelerator

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Commissioning beam data are treated as a reference and ultimately used by treatment planning systems, therefore, it is vitally important that the collected data are of the highest quality, in order to avoid dosimetric and patient treatment errors that may subsequently lead to a poor radiation outcome. High-energy photon and electron beams from different accelerators of the same nominal energy may have different dosimetric characteristics due to differences in target and flattening filter materials, accelerator guide and collimator designs. In the present study, clinically pertinent data for the available photon energy were investigated. For making measurements in water, first time in India, a three dimensional radiation field analyzer RFA (CRS- Scan –O-Plan) was used. For absolute dosimetry and other measurements like relative output factors, wedge factors etc., a DOSE1 electrometer (Scanditronix Wellhofer) in a white polystyrene was employed. All the measured data were utilized as an input to the ECLIPSE treatment planning system for further clinical use.

Key Words: commissioning, radiation field analyzer, electron beam, linear accelerator, dosimetry.

Introduction

The Clinac-DBX single energy medical linear accelerator manufactured by Varian Associates (Palo Alto, CA) has a single photon energy configuration 6 MV. Since commissioning beam data are treated as a reference and ultimately used by treatment planning systems, it is vitally important that the collected data are of the highest quality in order to avoid dosimetric and patient treatment errors that may subsequently lead to a poor radiation outcome. Determination of commissioning beam data should be performed with appropriate knowledge, proper tools and should be independent of the person collecting the data.

The accelerator has a 270° achromatic bending magnet to focus the electron beam on a copper target for the low energy photons and a composite tungsten and copper transmission target for high energy photons. Flattening filters of copper and nickel-steel with tungsten insert are used for proper flatness of the beams. Field size can be varied from 0.4×0.4 to 40×40 cm^2 at 100 cm SSD for the photon energies, and the output of the machine for a 10×10 cm^2 field size at the isocenter can be varied in three equal steps from 100 to 400 MU/min. For beam modification, wedge filters of 15° and 30°, made with steel are used for the maximum wedged field width of 20 cm, whereas the 45° and 60° wedges made with lead are used for the maximum wedged field width of 20 and 15 cm, respectively. Enhanced dynamic wedges of 10°, 15°, 20°, 25°, 30°, 45° and 60° are achieved by the movement of upper collimator jaws for a maximum wedged field width of 30 cm. The upper and lower set of collimator jaws have an additional feature of independent movement for defining asymmetric field with respect to the axis of the collimator rotation, thereby allowing the user the facility moving either of the upper jaw blocks, even beyond the centre of the cross wires towards the other jaw of maximum of 15 cm. Clinac – DBX also provide the Millennium - 80 multileaf collimator as tertiary collimator. It consists of 40 pairs of collimator leafs made up of tungsten with a height of 6 cm. 40 pair's project a width of 1 cm each at isocenter. These round ends MLC's provide a maximum field size of 40×40 cm^2.

High-energy photon beams from different accelerators of the same nominal energy may have different dosimetric characteristics due to differences in target and flattening filter materials, accelerator guide and collimator designs. Clinically pertinent data for single available photon energy were measured.

Materials and Methods

For making measurements in water, a three dimensional radiation field analyzer RFA-300 (CRS,Scan-O-Plan), which contains water phantom, lifting table, main control unit (MCU) and a dual probe with ionization chamber, were utilized. The chamber has a sensitive volume of 0.13 cc and the outer wall is made up of PMMA with an outer diameter of 7 mm. The water phantom has the scanning area dimensions of 520 × 530 × 400 (X/Y/Z). The positional reproducibility of the drive mechanics and positional accuracy is ± 0.1 mm and ± 0.5 mm, respectively. For absolute dosimetry and other measurements, like relative output factors, wedge factors etc., a DOSE1 electrometer (Scanditronix Wellhofer) in a white polystyrene phantom was employed.

Nominal photon beam energy was determined by measuring the ionization charge for a fixed source-to-detector distance (100 cm) at depths of 10 and 20 cm in water. The ratio of the 20 cm reading to the 10 cm reading (I_{20}/I_{10}) is related to the nominal accelerating potential.

The central axis percentage depth doses were measured with ionisation chamber in RFA system. Measurements were made at 100 cm SSD for field sizes from 3 × 3 to 40 × 40 cm^2. Isodose curves were plotted for the available field sizes up to 35 × 35 cm^2 for open portals and up to the width of 15 cm for the set of four wedge filters. Isodose plots were drawn using the data from the measurements with ionization chamber in the RFA system at the source to water level distance of 100 cm.

Relative output factors for all possible field sizes were measured using a FC65-G farmer type ionization chamber in a white polystyrene phantom at d_{max} relative to the 10 × 10 cm^2 field. Similarly, wedge factors for the four sets of physical wedges and for the EDW for both the energies were found out by making measurements for the wedged field and open field at d_{max} of 1.5 cm and taking the ratio of these measurements.

Field flatness and symmetry of the 6 MV photon beam was found out by using RFA for measuring inplane, cross plane and in diagonal plane beam profiles for the depth of $d_{max,}$ and 10 cm.

The correction factor for perspex tray attenuation was measured by using FC65-G farmer type ionization chamber in a white polystyrene phantom at 10 cm depth by taking the ratio of meter reading without and with the tray. Block transmission factor was found out by the ratio of fully blocked for a field size of 3 × 3 cm^2 meter reading to the blocking tray alone. Similarly MLC transmission factors found out by closing both A and B bank of MLC's.

Results and discussion

Photon beams

For 6 MV photons, the ionization ratio is found to be 0.6685. The PDD data for 6 MV photons and 10 × 10 cm^2 field size are presented in Table 1. PDD data from other studies for 6 MV photon beam [9-15] are also presented in the Table, for comparison. It can be seen, that there is no significant difference in PDDs, when compared with the similar machines.

Output factors for 6 MV photons are presented in the Table 2. Wedge factors for physical and EDW wedges are presented in Tables 3 and 4. Wedge angles measured for field sizes of 4 × 4 to 15 × 15 cm^2 varied from the nominal values of 15°, 30°, and 45° by ± 3°, and for the 60° wedge the maximum variation was found to be -7° for a 4 × 4 cm^2 field.

The cross beam profiles for the field size of 6 × 6 cm^2, 10 × 10 cm^2, 15 × 15 cm^2, 20 × 20 cm^2 are shown in Fig. 1. The isodose plots are shown in Fig. 2 for the field size of 10 × 10 cm^2. The beam flatness and symmetry of 6 MV photons measured at the depth of d_{max} are shown in Table 5 .Standard linac specification generally requires that beam flatness should be less than 3 % and the typical symmetry specification should be within 2%. Therefore, our measured values are well within limits.

Correction factor for the Perspex tray for low energy photon beam was found to be 0.9712. The block transmission factor was found to be 0.0114 and the MLC transmission factor was 0.0168.

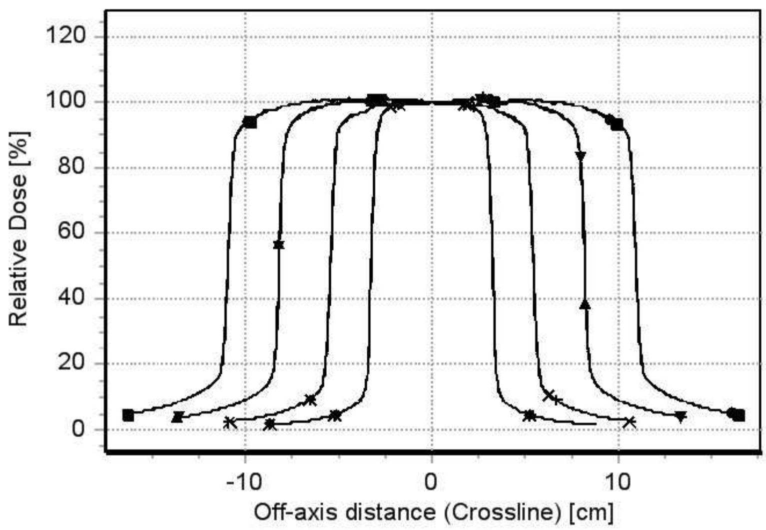

Figure 1. Cross beam profiles for the field size of 6x6 cm^2, 10x10 cm^2, 15x15 cm^2 and 20x20 cm^2, 6 MV photons.

Table 1. Percentage depth dose values for 6 MV X-rays from various accelerators, SSD -100 cm , field size – 10 x 10 cm^2

	Machine								
Depth(cm) in water	Mevatron[10] VI	Philips[11] SL-25	Leung[12]	Clinac[13] 2500	BJR -17[9]	Clinac 1800 CLF[14]	Clinac 1800 Texas[15]	Clinac 1800 KMIO[7]	Clinac DBX PMT RMC
1.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.0	99.0	99.4	99.0	98.0	98.1	99.2	98.6	98.7	99.7
3.0	95.5	95.5	95.0	94.1	94.0	95.8	94.8	94.6	95.8
4.0	91.5	91.5	91.0	90.4	90.8	91.3	90.3	91.5	91.7
5.0	87.5	87.0	86.5	86.8	87.3	87.4	87.2	87.4	87.4
6.0	83.0	83.0	82.5	82.5	83.5	83.0	82.7	83.5	83.3
7.0	79.0	79.2	78.5	78.4	79.2	79.0	78.4	78.3	79.2
8.0	75.0	75.5	74.5	74.5	75.2	75.0	74.3	74.1	75.2
9.0	72.5	71.7	70.8	70.7	71.3	71.4	70.4	70.2	71.4
10.0	68.5	68.1	67.0	67.0	67.7	67.7	66.7	66.5	67.7
11.0	65.5	64.6	63.5	63.7	64.2	64.3	63.2	63.0	64.1
12.0	61.5	61.2	60.0	60.5	60.9	60.8	59.9	59.2	60.7
13.0	58.0	58.0	57.0	57.4	57.8	57.7	56.7	56.5	57.4
14.0	55.0	55.0	54.0	54.4	54.8	54.5	53.8	53.7	54.4
15.0	52.5	52.2	51.3	51.6	52.0	51.8	51.0	51.0	51.5
16.0	49.0	49.3	48.5	48.8	49.4	49.0	48.3	48.2	48.6
17.0	46.5	46.7	46.0	46.2	46.8	46.5	45.8	45.8	45.9
18.0	44.0	44.2	43.5	43.6	44.4	44.0	43.4	43.3	43.4
19.0	42.0	41.9	41.3	41.2	42.1	41.7	41.1	40.9	41.0
20.0	40.0	39.7	39.0	38.8	40.0	39.4	39.0	38.5	38.7

Table 2. Relative output factors for 6 MV X-rays.

Field size cm^2	Relative output factor
3x3	0.879
4x4	0.906
5x5	0.929
6x6	0.947
8x8	0.977
10x10	1.000
12x12	1.018
15x15	1.040
18x18	1.057
20x20	1.066
25x25	1.086
30x30	1.102
35x35	1.115

Table 3. Wedge factors for physical wedges (6 MV X-rays)

Field size, cm^2	Wedge			
	15°	30°	45°	60°
5x5	0.781	0.618	0.491	0.404
10x10	0.781	0.618	0.490	0.405
15x15	0.784	0.623	0.493	0.409

Table 4. Enhanced dynamic wedge factors for 6 MV X-rays.

Field size cm^2	EDW wedge						
	10°	15°	20°	25°	30°	45°	60°
5x5	0.977	0.968	0.957	0.944	0.933	0.893	0.825
10x10	0.943	0.919	0.896	0.862	0.847	0.765	0.651
15x15	0.913	0.873	0.835	0.799	0.765	0.654	0.524
20x20	0.874	0.878	0.769	0.724	0.679	0.554	0.416

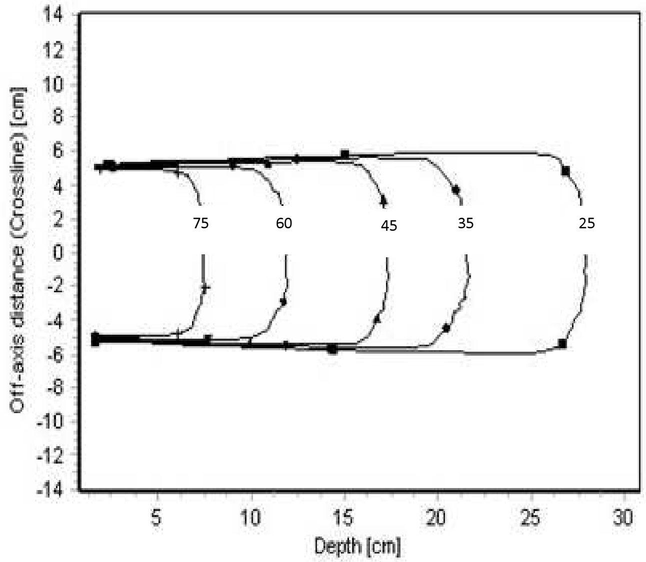

Figure 2. Isodoses for 6 MV photon beam for the field size of 10 x 10 cm^2

Table 5. Beam flatness and symmetry for 6 MV X-rays

Field Size cm^2	Inline		Crossline		Diagonal Angle 45°		Diagonal Angle135°	
	S (%)	F (%)	S (%)	F (%)	S (%)	F (%)	S (%)	F (%)
5x5	0.44	4.17	0.05	3.69	0.0	3.84	0.42	4.21
10x10	0.47	0.92	0.13	0.68	0.17	1.29	0.10	0.97
15x 15	0.59	1.52	0.03	1.5	0.22	1.55	0.26	1.51
20x20	0.60	1.91	0.01	1.72	0.04	1.73	0.25	1.65
25x 25	0.41	1.72	0.08	2.12	0.26	1.64	0.25	1.71
30x 30	0.28	1.92	0.16	2.31	0.46	1.35	0.03	1.87

Summary

Clinically pertinent data for the photon beam from the Clinac – DBX were measured and compared with similar beams available on other units. The central axis depth dose data are comparable to the averaged data of BJR supplement 17 for 6 MV X-rays, perhaps because of the use of the same material in the target and flattening filter in these accelerators. Wedge angles do not match with the specified angles, especially in the case of larger angle wedges, perhaps due to the beam flatness, which changes with the increasing field from middle trump to outer horns. These results may be useful in bringing home the point that the beams, even from the same type of machines, may be quite different and individualized measurements must be carried out for each of the available energies from each unit. All the measured data were utilized as an input to the ECLIPSE treatment planning system for the clinical use.

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