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Dosimetric Characterizations of Megavoltage Therapeutic Photon Beam

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This paper presents the dosimetric parameters characterizations of a megavoltage therapeutic photon beam. The main focus of this study is to investigate and analyze the parameters of percentage depth dose (PDD) and tissue maximum ratio (TMR) due to the importance of treatment system. The depth dose characteristics of 6MV photon beam for different field sizes in water phantom has been measured, analyzed and found a robustness results. The results revealed that the depth dose variation from 0.067% to 1.812% and the TMR values varies from 0.501% to 2.111%. It seems the measured dosimetric quantities are clinically relevant for different field sizes and depths.

Keywords: PDD; TMR; accuracy; LINAC; photon beam.

1. INTRODUCTION

Radiotherapy is applied with various techniques and equipment for local treatment of cancer all over the world. Most often, the equipment is used in radiotherapy to the patient irradiation are linear accelerators (LINAC) which delivers beam of X-rays in the range 4-30 MeV [1]. The exact

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determinations of radiotherapy parameters describing depth dose characteristics of photon beams are so essential for treatment planning [2-4]. To measure dosimetric parameters of radiotherapy homogeneous water phantom or equal medium should be used properly [1]. The dose distribution measurement in real patient is impossible [5]. So, all measurements have estimated by using water phantom for calculating the dose that can be applied to the actual patient for treating cancerous tissue [6-8]. The measurement of absorbed dose in the body depends on many factors (Photon energy, source to surface distance (SSD), field size and depth) [3]. During the treatment on radiotherapy it can be observed that the chance of cure may be decreased or increased in chance of irreversible damage 2 to 3 times if the dose delivery to the patient is decreased or increased by 10-15% [9]. In this case, the better recommendation of accuracy is ±5% in delivery of dose in radiotherapy as prescribed by ICRU [10] but the tolerance of 3.5% has been advised [11] that can be gained by tracking a strict quality assurance program [12]. In the quality treatment, the existing approaches use basically two setups (i) SSD and (ii) iso-centric to calculate the radio therapeutic dose for patients [13].

In the existing state-of-the-art techniques: the SSD setup by using 80cm Source to Surface Distance (SSD) for PDD measurements and isocentric setup by using 80cm Source to Axis Distance (SAD) for TMR measurements. These two setups are complex since the human body is inhomogeneous and different organs are located at different positions of the body also it needs more times.

To minimize the complexity of machine setup and save time for measuring the values of PDD and TMR for several clinical field sizes, this paper proposed a single setup by using 90cm Source to Surface Distance (SSD) as shown in Fig. 1.

2. MATERIALS AND METHODS

The Elekta Senergy Platform of 6MV photon beam and a PTW MP3-M water tank (PTW, Freiburg, Germany) with a scanning range of 50 cm × 50 cm × 40 cm is used in this work. Although various types of materials' phantoms are available recently but the water phantom is recommended for measurement due to the equivalent density of human tissue [14]. The PDD and TMR measurements have carried out along the CAX by using 0.125 cc active volume of semiflex (31010) ion chamber. Farmer type chamber of 0.6 cc (SN009016) is applied as reference. The PDD data have measured at a source-to-surface distance (SSD) of 90 cm for 10×10 cm^2 field size for various distances and also PDD have measured at 10 cm depth for square field sizes – 4 cm, 5 cm, 7cm, 10 cm, 15 cm, 20 cm, 30 cm and 40 cm. The TMR values are calculated from the measured depth dose. All measurements have made keeping both the gantry and collimator angles of the unit at 0 degrees [5] by using protocol of International Atomic Energy Agency (IAEA) TRS-398 [15]. The proposed experimental setup is shown in Fig. 1.

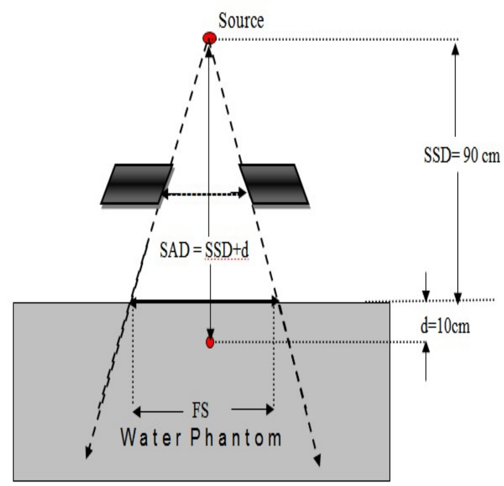


Fig. 1. The proposed SSD setup for dosimetric parameters measurements

The dosimetric data have measured by using the proposed setup and evaluated by MEPHYSTO-Navigation software at several depths and formulated for different depths with some rational step size [16]. The ratios of each of these readings on various depths and field sizes with point of maximum doses (1.5cm for 6MV photon) are build PDD and TMR values by using the equation (1) and equation (2) respectively.

$$\mathrm{PDD} = \frac{Dose\ at\ any\ depth}{Dose\ at\ r_f\ depth\ (d_{10})} \times 100 \qquad (1)$$

Where r_f depth (d_{10}) is the dose at 10cm depth

$$\mathrm{TMR} = \frac{Dose\ at\ any\ depth}{Dose\ at\ D_{max}} \qquad (2)$$

Where, the D_{max} for 4MV, 6MV and 15MV are 1.2cm, 1.6cm and 2.7cm respectively.

3. RESULTS

The characteristics of dose of photon beams can be assessed by its reduction with respect to its initial intensity in any medium. The decline in the beam intensity is observed owing to the attenuation of beam while entering the photon beam in the medium [3].

3.1 Percent Depth Dose (PDD)

The PDD have calculated by using equation (1) with 90cm SSD on water surface. The PDD value is tabulated in Table 1 and compared with standard published value [2]. The value has measured for a fixed 10cm×10cm field size with variation of distance and normalized to D_{max}. The graphical representation of PDD in various distances is shown in Fig. 2(a). It indicates that the PDD values have decreased with depth. Also the PDD value has calculated for different field sizes at a depth in water of 10cm and the value is tabulated in Table 2. The comparative study with standard data is observed in Fig. 2(b). If field sizes increase then the PDD value increase.

3.2 Tissue Maximum Ratio (TMR)

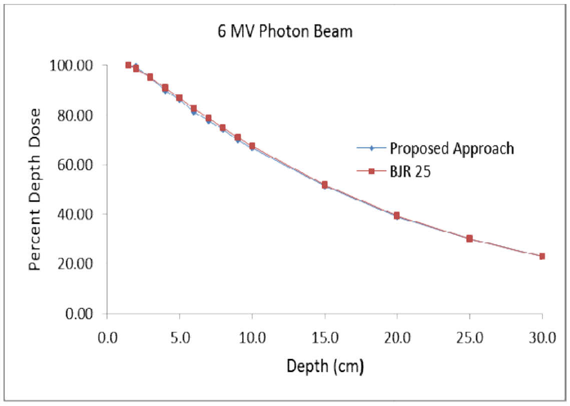
The TMR values have calculated by using equation (2) from the depth dose profile. The TMR values are tabulated in Table 3 and compared with standard published value BJR 25. The value has measured for a fixed 10cm× 10cm field size with variation of distances in water. The graphical representations of TMR at various distance is observed in Fig. 3(a). It indicates that the TMR value decreases while increasing depth. And also the TMR value has calculated for various field sizes at the depth in water of 10cm and the value is tabulated in Table 4. Fig. 3(b) shows the graphical representations of the comparative study. It indicates that the TMR value increases while the field size increases.

Table 1. Comparison of PDD data at various depths between proposed approach and BJR 25 published data [2] of 6MV Photon beam

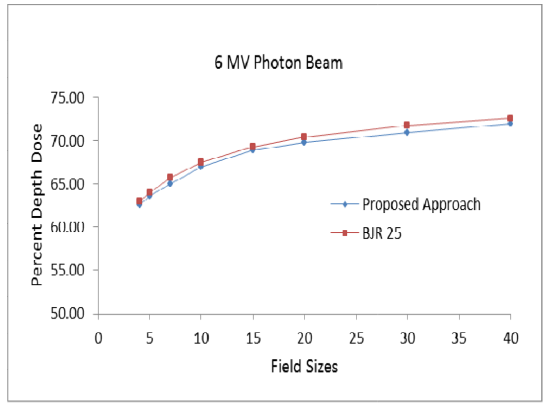
Sr. No.	Depth (cm)	Proposed Approach (%)	BJR 25 (%)	% Variation	R^2 Value (Proposed Approach)	R^2 Value (BJR 25)
1.	1.5	100.00	100.00	0.000		
2.	2	99.30	98.80	-0.506		
3.	3	95.10	95.10	0.000		
4.	4	89.80	91.00	1.319		
5.	5	86.40	86.90	0.575		
6.	6	81.30	82.80	1.812		
7.	7	77.90	78.80	1.142	0.9997	0.9999
8.	8	74.10	74.90	1.068		
9.	9	70.00	71.10	1.547		
10.	10	66.60	67.50	1.333		
11.	15	51.30	51.70	0.774		
12.	20	38.90	39.30	1.018		
13.	25	29.92	29.90	-0.067		
14.	30	22.90	22.80	-0.439		

Table 2. Comparison of PDD data for various field sizes at 10 cm depth between proposed approach and BJR 25 published data [2] of 6MV Photon beam

Sr. No.	Field Size (cm^2)	Proposed Approach (%)	BJR 25 (%)	% Variation	R^2 Value (Proposed Approach)	R^2 Value (BJR 25)
1.	4×4	62.58	63.0	0.667		
2.	5×5	63.55	64.0	0.703		
3.	7×7	64.97	65.7	1.111		
4.	10×10	66.97	67.5	0.785	0.9997	0.9999
5.	15×15	68.90	69.3	0.577		
6.	20×20	69.80	70.4	0.852		
7.	30×30	70.93	71.7	1.074		
8.	40×40	71.90	72.5	0.828		



(a)



(b)

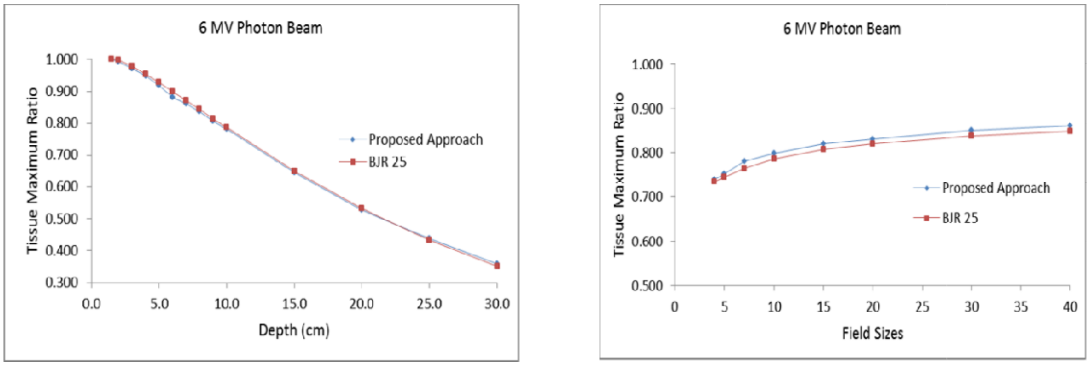
Fig. 2. Comparison of PDD data in water phantom (a) against depth for 10×10cm^2 field size, (b) against field sizes at 10 cm depth with published data of BJR 25 [2]

Table 3. Comparison of TMR data at various depths between proposed approach and BJR 25 published data [2] of 6MV Photon beam

Sr. No.	Depth (cm)	Proposed Approach (%)	BJR 25 (%)	% Variation	R^2 Value (Proposed Approach)	R^2 Value (BJR 25)
1.	1.5	1.000	1.000	0.0000		
2.	2.0	0.993	0.998	0.5010		
3.	3.0	0.971	0.979	0.8172		
4.	4.0	0.948	0.954	0.6289		
5.	5.0	0.918	0.928	1.0776		
6.	6.0	0.881	0.900	2.1111	0.9998	0.9999
7.	7.0	0.862	0.871	1.0333		
8.	8.0	0.837	0.843	0.7117		
9.	9.0	0.806	0.814	0.9828		
10.	10.0	0.781	0.786	0.6361		
11.	15.0	0.645	0.650	0.7692		
12.	20.0	0.528	0.532	0.7519		
13.	25.0	0.439	0.433	-1.3857		
14.	30.0	0.358	0.352	-1.7045		

Table 4. Comparison of TMR data for various field sizes at 10 cm depth between proposed approach and BJR 25 published data [2] of 6MV Photon beam

Sr. No.	Field Size (cm^2)	Proposed Approach (%)	BJR 25 (%)	% Variation	R^2 Value (Proposed Approach)	R^2 Value (BJR 25)
1.	4×4	0.740	0.735	-0.680		
2.	5×5	0.753	0.745	-1.074		
3.	7×7	0.780	0.765	-1.961		
4.	10×10	0.799	0.786	-1.654		
5.	15×15	0.820	0.808	-1.485	0.9992	0.9999
6.	20×20	0.830	0.82	-1.220		
7.	30×30	0.850	0.837	-1.553		
8.	40×40	0.861	0.848	-1.533		



(a) (b)

Fig. 3. Comparison of TMR data in water phantom (a) against depth for 10×10cm^2 field size, (b) against field sizes at 10 cm depth with published data of BJR 25 [2]

From the above analysis and discussion it indicates that the PDD and TMR for 6MV photon beam for 10cm×10cm field size at the different depths shows variations from 0.067% to 1.812% (R^2 = 0.9997) and 0.501% to 2.111% (R^2 = 0.9998) respectively. It also shows for different field sizes at 10cm depth the variations from 0.667% to 1.111% (R^2 = 0.9997) and 0.680% to 1.961% (R^2 = 0.9992) for PDD and TMR respectively. These results shows an optimistic assign with BJR 25 (R^2 = 0.9999).

4. DISCUSSION

Dosimetric accuracy and good planning are very essential for actual delivery of radiation to the cancerous tissues [12]. Many a researcher have worked and performed on the characteristics of various x-ray beams [7,8,14,17-19] by using two setups. The main focus of this research is that all measurements have carried out by using one setup. The PDD values are explained by Cakir T. et, al [20] that reports the %age variation of 0.02 to 3.69%. The TMRs value with %age variation of 0.101 to 2.49% was reported by Akinlad-e B.I. et, al. [21]. The proposed study carried out %age variations of PDD and TMR values are so well sign for 10cm×10cm field size. For several field sizes the %age variation for PDD and TMR values are within 2%. These results show less %age variation than the previous cases [20,21].

5. CONCLUSION

This research proposed a technique which measures the PDD and TMR values by using a single setup. The proposed technique has examined properly with several clinical field sizes. Since, the proposed technique saves enough time. This procedure will be quite beneficial for the treatment modalities of cancer patients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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