Measurement of Percentage Depth Dose of a Linear Accelerator for 6 MV and 10 MV Photon Energies

R. N. Sruti[1, 2], M. M. Islam[1*], M. M. Rana[3], M. M. H. Bhuiyan[1], K. A. Khan[2]
M. K. Newaz[4] and M. S. Ahmed[4]

[1]*Health Physics and Radioactive Waste Management Unit, Institute of Nuclear Science & Technology Bangladesh Atomic Energy Commission, Dhaka*
[2]*Department of Physics, Jagannath University, Dhaka*
[3]*Department of Oncology, Bangabandu Sheikh Mujib Medical University, Dhaka*
[4]*Institute of Computer Science, Bangladesh Atomic Energy Commission, Dhaka*

Abstract

During commissioning of a linear accelerator (LINAC) one of the essential parameters known as percentage depth dose (PDD) which must be obtained prior to clinical use. In this study the measurements for PDDs were performed at National Institute of Cancer Research & Hospital (NICRH), Mohakhali, Dhaka, Bangladesh using a linear accelerator (Model D-2300CD, Varian medical systems) with 6 MV & 10 MV photon energies for a set of 12 field sizes (3 × 3, 4 × 4, 6 × 6, 8 × 8, 10 × 10, 12 × 12, 15 × 15, 20 × 20, 25 × 25, 30 × 30, 35 × 35 and 40 × 40 cm^2), keeping the same conditions (e.g., geometry, ion chamber voltage and polarity, incremental step and direction). The measurement of PDDs were performed by two Semiflex ionization chambers (S/N: 1222, S/N: 1217) from PTW for the linear accelerator (Model D-2300CD, Varian medical systems) using 3D water phantom (MP3) and MEPHYSTO mc^2 software from PTW. The calculation of PDDs were done using a beam analysis tool of TPS (Varian eclipse, Version: 10.0.28). The measured PDD curves were obtained for 6 and 10 MV photon beams with above mentioned field sizes and compared with PDD curves and treatment planning system (TPS) calculated PDD curves of the British Journal of Radiology- 25 (BJR-25, standard PDD protocol). The measured depth dose (D_{max}) for reference field size (FS) 10 × 10 cm^2 are15.99 mm and 24.71 mm and the PDD at 10 cm depth (D_{10}) are 66.87% and 74.01% for 6 MV and 10 MV photon energies, respectively. The results obtained for depth dose (D_{max}) and PDD at 10 cm depth (D_{10}) for both 6 MV and 10 MV photon energies are found within the limit. The measured PDD curves for both photon energies show a good agreement with the BJR-25 PDD curves and TPS calculated PDD curves.

Keywords: Percentage depth dose, LINAC, cancer, TPS phantom

1. Introduction

The inception of radiotherapy soon after the discovery of X rays by Roentgen in 1895, the technology of X-ray production has first been aimed towards ever higher photon and electron beam energies and intensities and more recently towards computerization and intensity modulated beam delivery [1]. The production of radiation using sophisticated devices like LINAC is useful tools for clinical application. The radiations produced by LINAC have many advantages over the traditional X-ray machine. The concurrently developed medical LINACs became the most widely used radiation source in modern radiotherapy [2]. Most of the developed countries are using linear accelerator as basic treatment machine. A linear accelerator (LINAC) customizes high energy x-rays to conform to a tumor's shape and destroy cancer cells while sparing surrounding normal tissue [3]. High power LINACs are also being developed for production of electrons at relativistic speeds [4].

The LINAC can be used for therapy (treatment) after completion of some satisfactory scientific methods called as pre-commissioning testing. The process of commissioning a LINAC for clinical use includes comprehensive measurements of dosimetric parameters that are necessary to validate the TPS used to select optimal radiation modality and treatment technique for individual patients [5]. Therefore, it is essential to have a minimum data set which includes percentage depth dose (PDD), Profile and Output characterization for a series of field sizes (FSs).

In this study, one basic dosimetric parameter like PDD for 6 MV and 10 MV photon beams with different FSs was measured. These measurements have been performed in a three dimensional (3D) computer controlled water phantom (PTW MP3) using semiflex ionization chamber (S/N 1217) and semiflex ionization chamber (S/N 1222) for the varian linear accelerator model D-2300CD machine at radiation Oncology Department, National Institute of Cancer Research and Hospital, Mohakhali, Dhaka. The data obtained during the initial commissioning of LINAC can be treated as the standard data for clinical purpose. The scientific methods used for commissioning of modern Linear Accelerator are really a time consuming procedure and needs dedication in work [5]. The aim of this work is to measure one of the essential dosimetric parameters for commissioning of a LINAC. The measured parameter can be used as a reference data for clinical use to ensure that the experimentally obtained parameters have not changed during normal operation of the LINAC system.

2. Materials and Methods

2.1 Instrumentation

In this study, the linear accelerator was varian D-2300 CD, with dual energy mode, having both photon and electron beam facility. It has two photon energies e.g. 6 MV and 10 MV and five electron energies (e.g. 4 MeV, 6 MeV, 9 MeV, 12 MeV and 15 MeV).

[*]Corresponding author: moinul19@hotmail.com

Percentages of depth dose for 6 MV and 10 MV photon energies were measured by using a 3D water phantom, PTW 31010 semiflex chamber (S/N 1217) as a field chamber and PTW 31010 semiflex chamber (S/N 1222) as a reference chamber and MEPHYSTO mc^2 software version 1.6. The PDD calculation was performed by using eclipse external treatment planning system (Version 10.0.28).

2.2 Percentage Depth Dose (PDD) Measurement

Typically, during the first commissioning, the measurement of PDD at central axis is an essential part. One way of characterizing the central axis dose distribution is to normalize dose at depth with respect to dose at a reference depth. PDD is defined as the quotient, expressed as a percentage of the absorbed dose at any depth Q to the absorbed dose at a fixed Reference depth P, along the central axis of the beam as shown in Fig. 1.

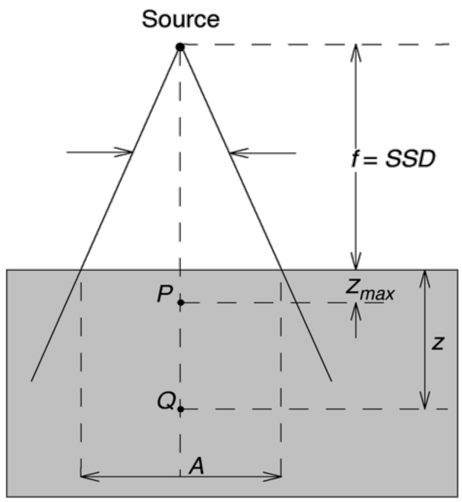

Fig. 1 The setup measurement for PDD

Percentage depth dose (P) is thus:

$$P = \frac{D_Q}{D_P} \times 10$$

Where, P is the percentage depth dose, D_Q is the absorbed dose at any depth Q and D_P is the absorbed dose at a fixed Reference depth P.

2.2.1 Measurement Setup for Percentage Depth Dose (PDDs) Curves

To measure PDD it is necessary to set up phantom and ionization chambers at isocentre alignment of the LINAC system. In this regard, the phantom and chambers were placed in isocentric distance of the LINAC having 6 MV and 10 MV photon energies. The MP3 water tank was leveled with spirit level and the source to water surface distance was set to 100 cm using the front pointer device.

In percentage depth dose (PDD) measurement, an ionization chamber is at zero depth when the chamber's effective point of measurement (EPOM) is aligned with water surface. According to IAEA dosimetry protocol, the EPOM of a field chamber is shifted downstream by half of the chamber's inner radius (0.5r) [6]. This means that after the reference point has been temporarily aligned with water level, the chamber was moved downstream by the same distance, and zero set again. A reference chamber (S/N1217) was set in the corner of the measuring field just above the water surface. Fig. 2 shows the phantom setup for PDD measurements.

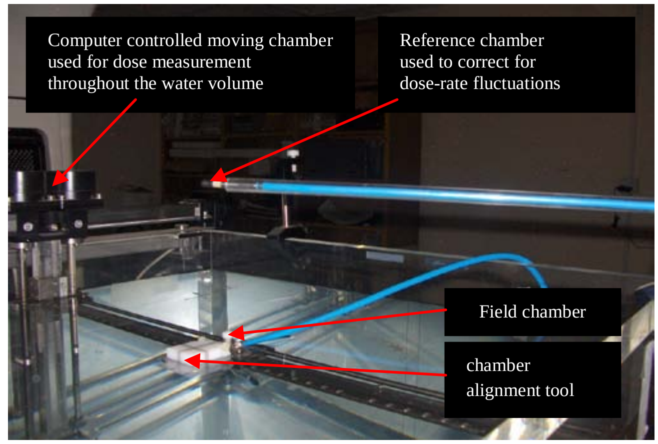

Fig. 2 Phantom setup for PDDs measurements

The PDD scanning was performed starting from 300 mm depth to 0 mm depth in upward direction throughout the phantom to avoid the water turbulence.

The PDD was measured from the phantom surface at 0 cm to a depth of 30 cm along Central Axis (CAX) having measurement interval 1 mm from surface to 2 cm depth and then 2.5 cm up to 25 cm. The PDD measurement duration for each point was 0.1 second.

Scanning was controlled by PTW MEPHYSTO mc^2 software version 1.6.2. Step size was 1 mm between surface and 20 mm depth, and 2.5 mm at larger depths. Measurement time was 0.1 s per point.

The percentage of depth dose (PDD) curves were acquired for 12 square field sizes: 3 × 3, 4 × 4, 6 × 6, 8 × 8, 10 × 10, 12 × 12, 15 × 15, 20 × 20, 25 × 25, 30 × 30, 35 × 35 and 40 × 40 cm^2. The field size was defined by jaws, not multileaf collimator (MLC). During the PDD measurement the water level of 3D water phantom was always checked with the front pointer before the first scan. Because of the room temperature evaporation can take place therefore the water tank must be filled up with water in every 30 minutes to maintain the source to water surface distance constant.

The following procedures were applied to process the collected data from the scanning of 3D water phantom in order to plot PDD: The curves were smoothed in MEPHYSTO mc^2 software. To create PDD curves with equidistant (1mm) measuring points were performed. The PDD curves were plotted for 6 MV and 10 MV photon energies for LINAC system.

3. Results and Discussion

The measured PDD values of 6 MV and 10 MV photon energies for all 12 FSs were plotted to obtain PDD curves. The measured PDD curves for reference 10 x10 cm^2 FS at 100 cm source to surface distance (SSD) of 6 MV and 10 MV photon energies have been shown in figs 3(a) and 3(b).

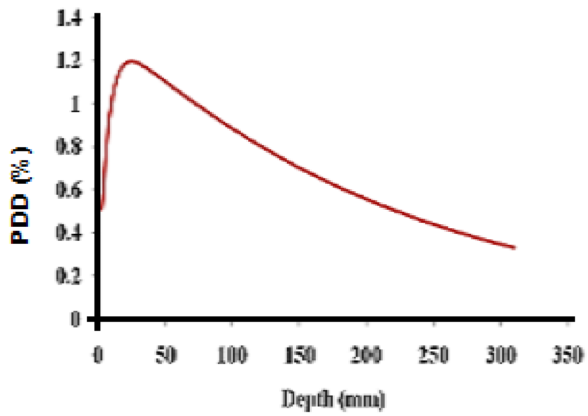

Fig. 3(a) Measured PDD curve for 6 MV energy

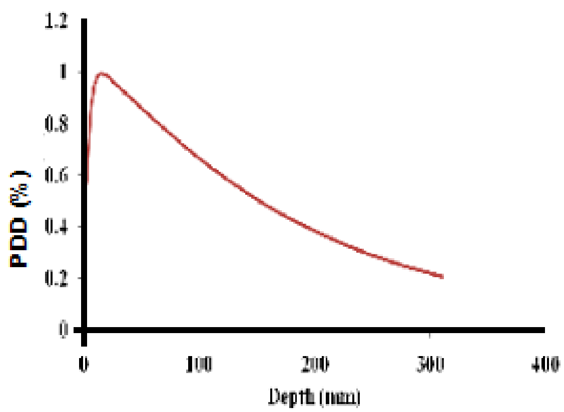

Fig. 3(b) Measured PDD curve for 10 MV energy

The depth dose (D_{max}) and PDD at 10 cm depth (D_{10}) for 6 MV and 10 MV photon energies for 10 x10 cm^2 FS obtained from Fig. 3(a) and 3(b) are given in Table 1

Table 1. Measured D_{max} and D_{10} for 10 x 10 cm^2 FS of 6 MV and 10 MV photon energies

Energy (MV)	FSs (cm^2)	Depth dose D_{max}(mm)	PDD at 10 cm depth D_{10} (%)
6	10 x 10	15.99	66.87
10	10 x 10	24.71	74.01

The depth dose (D_{max}) for FS 10 × 10 cm^2 for 6 MV and 10 MV photon energies are 15.99 mm and 24.71 mm respectively and the PDD at 10 cm depth (D_{10}) are 66.87% and 74.01% respectively. According to IEC 60731 Scale, the tolerances for 6 MV and 10 MV photon energies for D_{max} are 1.5±.2 cm and 2.3±.2 cm, respectively and for D_{10} are 67.1±1.5 % and 73.1±1.5 % respectively [7]. The result obtained for depth dose (D_{max}) and PDD at 10 cm depth (D_{10}) for both 6 MV and 10 MV photon energies are found within the limit mentioned in the IEC 60731 scale [7].

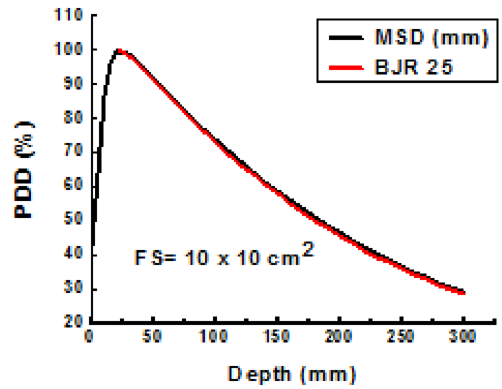

Fig. 4(a) Compared PDD curve for 6 MV energy

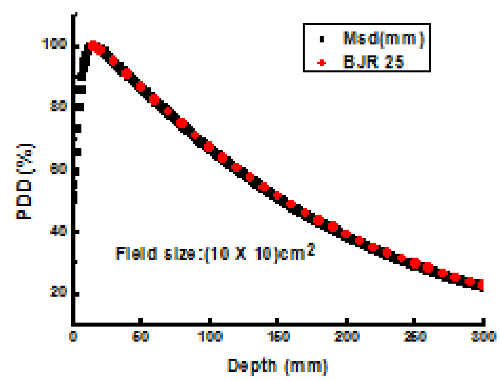

Fig. 4(b) Compared PDD curve for 10 MV energy

3.1 Comparison with BJR 25

In order to justify the measured PDD data, all the measured PDD data obtained from 6 MV and 10 MV photon energies were compared with the standard PDD protocol BJR 25 [8]. The compared curves between measured PDD values and BJR 25 PDD values for 6 MV and 10 MV photon energies for reference 10 × 10 cm^2 FS is given in Figs 4(a) and 4(b). From the compared curves, it is evident that the measured PDD shows good agreement with BJR 25.

3.2 Comparison with TPS Calculated PDD using Beam Analysis Tool

The measured PDD values for 6 MV and 10 MV photon energies were compared with the TPS calculated 6 MV and 10 MV PDD values by using beam analysis tool. The compared curves between measured PDD values and TPS calculated PDD values for 6 MV and 10 MV photon beam for reference 10 × 10 cm^2 FS is given in Figs 3(a) and 3(b).

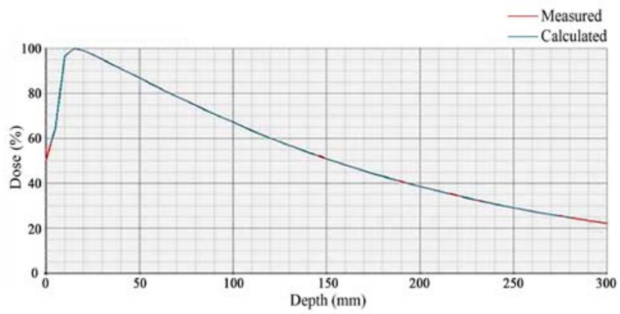

Fig. 5(a) Measured and calculated depth dose, 6 MV photon, FS: 10×10 cm^2

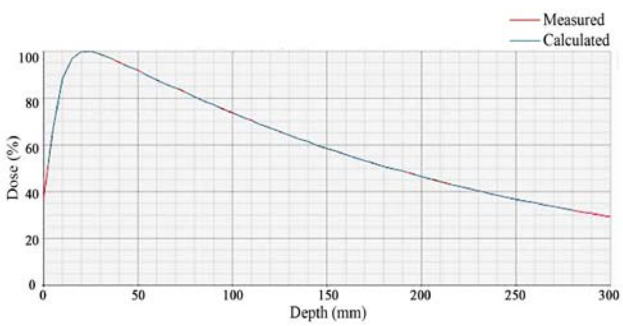

Fig. 5(b) Measured and calculated depth dose, 10 MV photon, FS: 10 × 10 cm^2

Results from the comparison of the measured and the calculated depth dose curve (PDDs) for 6 MV and 10 MV photon energies for 10 x 10 cm^2 FS are shown in Table 2.

Table 2 Difference between TPS calculated and measured depth dose curves for 6 MV and 10 MV photon energies for 10 x 10 cm^2 FS

Energy (MV)	Square field Size (cm^2)	Depth difference (mm) at max. dose	Depth difference (mm) at 50% dose	Dose difference (%) at 100 mm depth	Dose difference (%) at 200 mm depth
6	10 x 10	-0.025	0.084	-0.056	-0.001
10	10 x 10	-0.025	-0.150	0.305	-0.021

According to AAPM TG-40 protocol the difference between TPS calculated PDD and measured PDD for 6 MV and 10 MV photon energies using beam analysis tool in TPS were found within ±2mm.

4. Conclusion

The process of commissioning a LINAC for clinical use includes comprehensive measurements of dosimetric parameters. Commissioning of a LINAC is a process where a full set of data is acquired that will be used for patient treatment. The essential parameters that include percentage depth dose (PDD), Profiles and Output characterization for a series of Field Sizes (FSs) are the important dosimetric data that requires in the commissioning process of a LINAC system. Since the outcome of radiation treatment is directly related to the precession in the delivered dose to the patient that is dependent on the accuracy of beam data used in the treatment planning process. Therefore, to operate a LINAC system for treatment purpose, the percentage depth doses is needed to measure correctly.

The measured results are verified by following the International Electrotechnical Commission (IEC 60976) protocol. For the quality assurance (QA) purpose, The British Journal of Radiology volume 25 (BJR 25), The American Association of Physicists in Medicine - Task Group- 40 (AAPM TG 40) were followed.

D_{max} and D_{10} for 6 MV and 10 MV photon beam were found within the limit mentioned in the IEC 60976 Scale. The compared curve between the measured PDD and BJR 25 for all FSs show a good agreement. From Table 2 the differences between measured PDDs and TPS calculated PDDs for 6 MV and 10 MV photon energies are ±2 mm.

The PDD data obtained for 6 MV and 10 MV photon energies in this work will be useful for initial commissioning of LINAC system. However, further work can be done to verify the measured data for clinical use.

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