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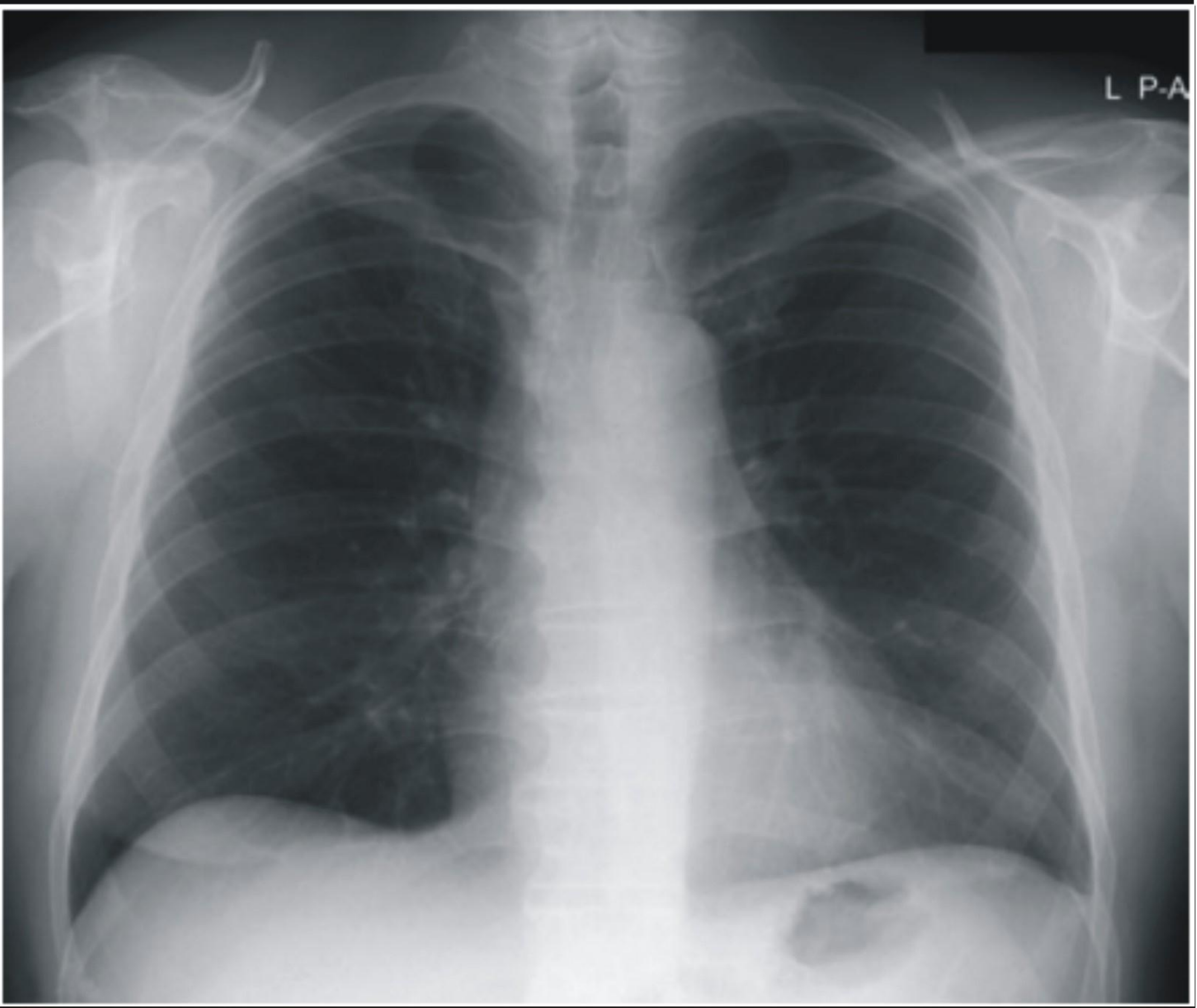

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Comparison of Calculated Percentage Depth Doses at Extended Source-to-Surface Distance for 6 MV And 15 MV Photon Beam of a Linear Accelerator

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ABSTRACT

Background: Research findings from percentage depth dose (PDD) are crucial in evaluating patient doses received in radiation therapy.

Objective: To compare calculated percentage depth doses at an extended source-to-surface distance (SSD) for 6 MV and 15 MV photon beams of a linear accelerator.

Methodology: Measured PDD values of the 100 cm source to surface distance (SSD) and calculated values at extended SSDs for 6 MV and 15 MV photon beams of an Elekta NHA SLi 1998 linear accelerator were analyzed. The PDD data was collected by placing ionization chamber inside water phantom for depths ranging from z = 0 - 30 cm in a water phantom and using a square field sizes of 10 x 10 cm^2. Photon energies of 6 MV and 15 MV were used for the measurement, with both gantry and collimator angles fixed at zero degree. PDD was calculated at extended SSD of 110 cm, 120 cm, 130 cm, and 140 cm from the measured PDD values of 100 cm SSD for both 6 MV and 15 MV photon energies using Mayneord factor.

Results: The depth dose maximum (D_{max}) for field size 10 x 10 cm^2 for 6 MV and 15 MV photon energies were 1.62 cm and 2.65 cm, respectively and the PDD at 10 cm (D_{10}) were 67.9% and 75.9%, respectively. The mean deviation of the calculated PDD at extended SSDs was found to be between 0.2% and 1%.

Conclusion: The calculated PDD values at extended SSDs are considered suitable for clinical use at all clinically relevant depths and field sizes.

Keywords: Percentage depth dose (PDD), extended source to surface distance, linear accelerator.

Introduction

A significant component of the total dose delivered to a tumour and surrounding tissues during radiation treatment arises from the scattering of the primary beam [1, 2]. This relationship can be put to practical use in calculation of approximate doses under widely different conditions of radiation.

The PDD is calculated by dividing the intensity measured at depth by that measured at the surface [3]. However, if further increase of the dose at shallow depths is desired, modifying device can be employed. On the basis of clinical dose-response data, the International Commission on Radiation Units and Measurement (ICRU) recommended that dosimetry systems must be capable of delivering dose to an accuracy of 5%. Extended source-to-surface distance (SSD) treatment refers to treatment where the SSD is greater than 100 cm. It is achieved by changing the position of the couch relative to the treatment head [4].

An extended source-to-surface distance (SSD) is often employed in half-body irradiation (HBI) and total-body irradiation (TBI) to obtain fields sufficiently large to encompass the total body. It is clinically desirable to administer a uniform dose to all tissues, including the surface, especially to counteract the skin-sparing of high energy x-rays. The electrons generated from the air contribute more to the dose near the surface at extended distances than at regular SSDs [5, 6].

Many factors contribute to both random and systematic deviations in dose delivery, including daily patient setup, target delineation, and dose calculation. It is desirable that the errors associated with each step of the treatment process must be substantially less than the overall tolerance. Thus, as improvements are made in immobilization techniques, patient setup, and image quality, similar improvements are necessary for dose calculations to obtain greater accuracy in overall dose delivery [6, 7].

The accurate determination of dose per monitor unit (MU) at a single calculation point is an essential part of this process. The objective of the study was to compare calculated percentage depth doses at an extended source to surface distance for 6 MV and 15 MV photon beams of an Elekta NHA SLi 1998 linear accelerator.

Materials and methods

This was a prospective cross-sectional experimental study carried out at the radiotherapy facility of National Hospital, Abuja. The PDD data of 6MV and 15MV photon energies for an Elekta NHA SLi 1998 linear accelerator was collected and analyzed using MatLab version 2014 software.

Measurement of nominal Percentage Depth Dose (PDD)

The percentage depth dose data were collected by placing ionization chamber inside the water phantom. Since the rails restrict the movement of the chamber in the direction aligned with the water tank, proper water tank alignment is important so that the ionization chamber is tracked along the beam axis to allow for depth dose data collection. For practical reason, the water surface was set at the 100 cm source-to-surface distance (SSD). Shown in Figure 1 is the set-up of the experiment:

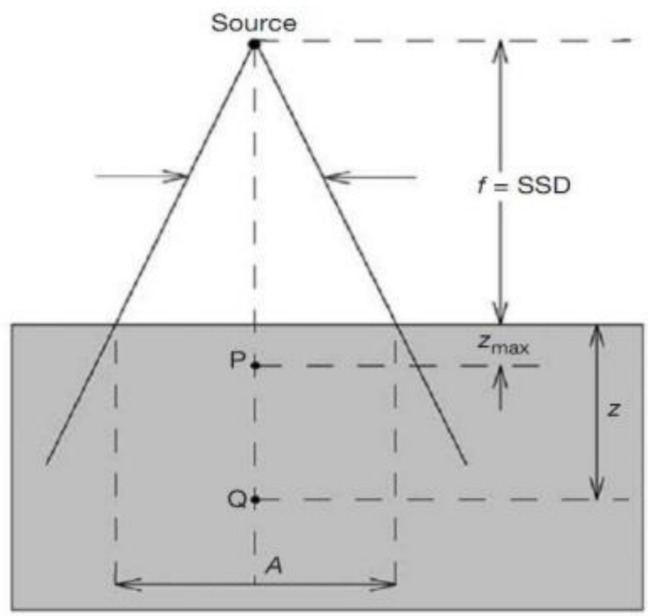

Figure 1. The geometry of PDD measurement. Point Q is an arbitrary point on the beam central axis at depth of z, point P is the point at z_{max} on the beam central axis. The field size A is defined on the surface of the phantom [7].

The percentage depth dose data were collected for depths ranging from z = 0 cm to z = 30 cm in a water phantom, and using a square field size of 10 x 10 cm^2. Photon energies of 6 MV and 15 MV were used for the measurements. During these measurements, both gantry and collimator angles were fixed at zero degree. The measurements of PDD for each depth in a water phantom took 30 seconds. The data was then normalized to the maximum dose and expressed as a percentage.

Derivation of calculated values of Percentage Depth Dose (PDD) at extended distance.

During commissioning of the linear accelerator, the depth dose data were collected for a range of field sizes from 4 x 4 cm^2 to 40 x 40 cm^2 for a particular photon beam quality with the setup at the nominal SSD (100 cm). To convert percent depth dose (PDD) from one SSD to another, the Mayneord factor, which is derived solely from inverse square law considerations, is used. The conversion formula is given as:

$$PDD_2\,(d, SSD_2, S) = PDD_1\,(d, SSD_1, S) \times F \ldots (1)$$

Where:

d = depth

SSD_1 = nominal distance (100 cm)

SSD_2 = extended distance (110, 120, 130, and 140 cm respectively)

S = field size at surface (10 x 10 cm^2)

F represents the corresponding Mayneord's factor and is given by:

$$F = \left(\frac{SSD1+d}{SSD1+dmax}\right)^2 x \left(\frac{SSD2+dmax}{SSD2+d}\right)^2 \ldots\ldots(2)$$

The depth dose data collected during commissioning were adopted for calculating the PDD value at extended SSDs (110, 120, 130, and 140 cm, respectively) [4, 8].

The measured PDD values were verified by following the international Electro-technical Commission (IEC 60976) protocol [5], as well as recommendations found in the literature.

Results

The measured PDD values for 6 MV and 15 MV photon energies for all field sizes (FS) at SSD of 100 cm were plotted to obtain PDD curves. The measured PDD curves for reference 10 x 10 cm^2 FS at 100 cm SSD of 6 MV and 15 MV photon energies are shown in Figures 1, 2 and 3. The depth dose (D_{max}) and PDD at 10 cm depth (D_{10}) for 6 MV and 15 MV photon energies for 10 x 10 cm^2 FS obtained from Figure 2(a) and 2(b) are given in Table 1.

The depth (D_{max}) for FS 10 x 10 cm^2 for 6 MV and 15 MV photon energies are 1.62 cm and 2.65 cm respectively and the PDD at 10 cm depth (D_{10}) are 67.9% and 75.9%, respectively. According to IEC 60731 Scale, the tolerances for 6 MV and 15 MV photon energies for D_{max} are 1.5 ± 0.2 cm and 2.5 ± 0.2 cm, respectively and for D_{10} are 67.1 ± 1.5% and 75.1 ± 1.5%, respectively. The result obtained for depth dose (D_{max}) and PDD at 10 cm depth (D_{10}) for both 6 MV and 15 MV photon energies are found within the limit mentioned in the IEC 60731 scale [5].

The Mayneord factor given by equation (1) and (2) was used to derive values of percentage depth dose at extended SSD of 110, 120, 130, and 140 cm, respectively. The PDD at extended SSD of 110, 120, 130, and 140 cm for 10 x 10 cm^2 FS for each of 6 MV and 15 MV photon energies are shown in Figure 3(a) and 3(b).

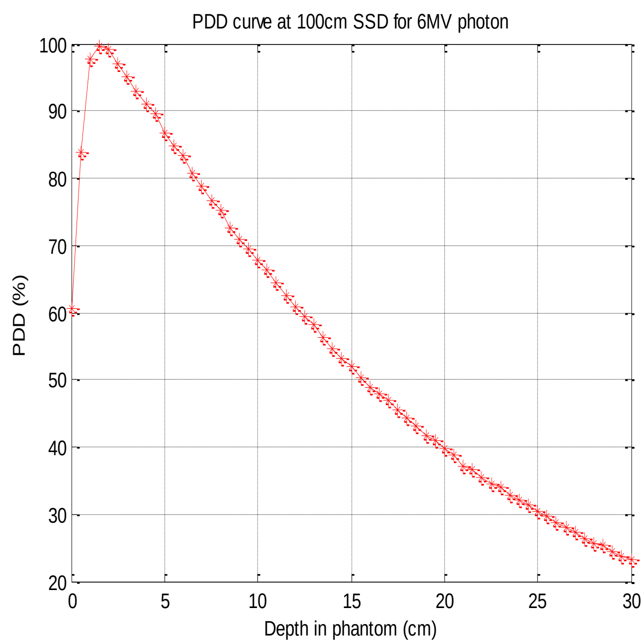

Figure 2(a). *Measured percentage depth-dose curve for 6 MV energy determined at 100 cm SSD.*

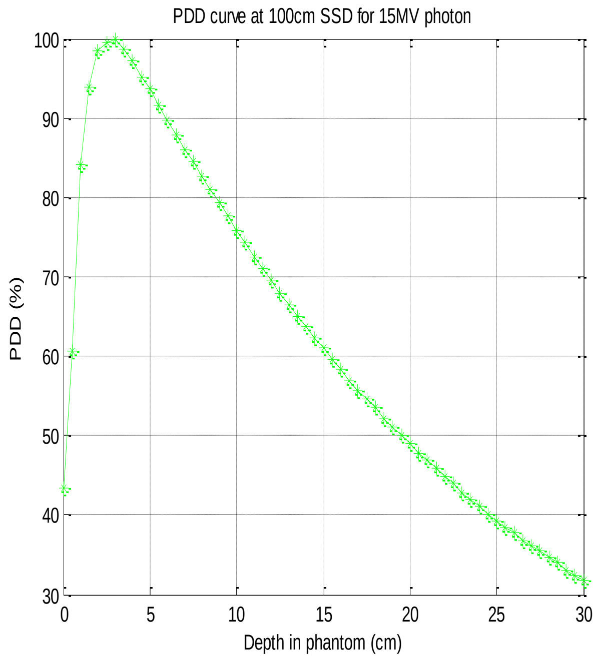

Figure 2(b). *Measured percentage depth dose for 15 MV energy determined at 100 cm SSD*

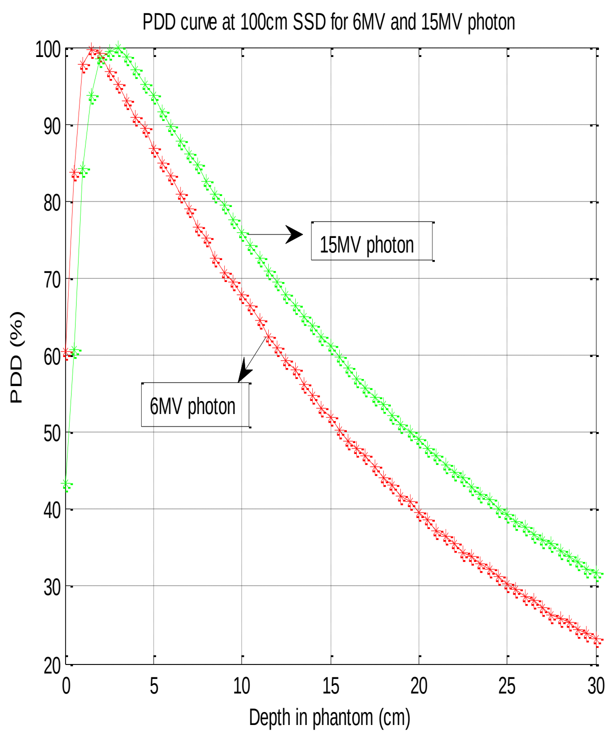

Figure 2(c). *Compared percentage depth-dose curves for 6 MV and 15 MV energy determined at 100 cm SSD.*

Table 1. Measured D_{max} and D_{10} for 10 x 10 cm^2 field size of 6 MV and 15 MV photon energies

Energy (MV)	Field Size (cm^2)	Depth dose max D_{max} (cm)	PDD at 10cm Depth D_{10} (%)
6	10 x 10	1.62	67.9
15	10 x 10	2.65	75.9

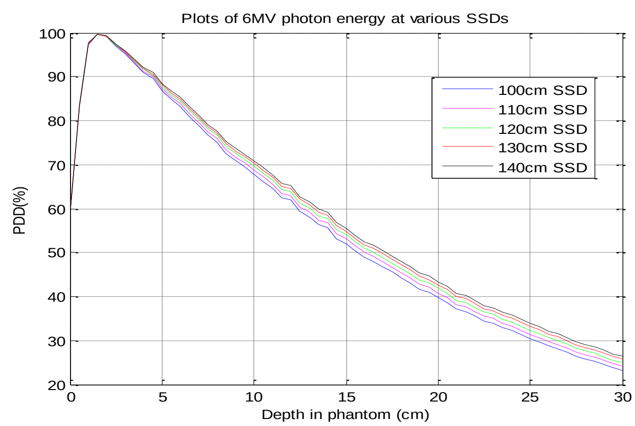

Figure 3(a). *Comparison between calculated values of percentage depth dose determined at extended SSD for 6 MV energy.*

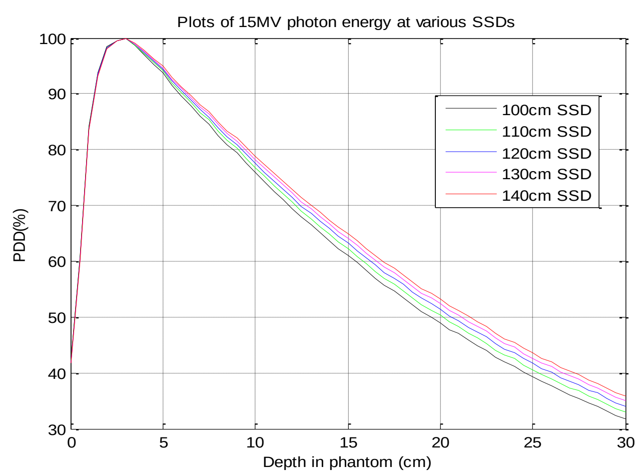

Figure 3(b). *Comparison between calculated values of percentage depth dose determined at extended SSDs for 15 MV energy.*

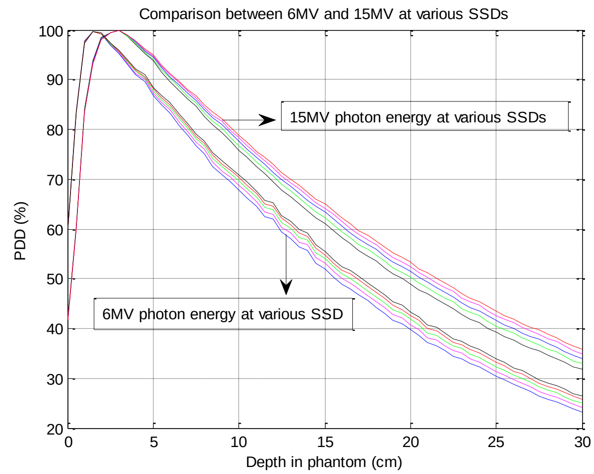

Figure 3(c). *Compared calculated PDD curve at extended SSD for 6 MV and 15 MV photon energies.*

Discussion

Radiation therapy is an established method of cancer treatment. New technologies in cancer radiotherapy need a more accurate calculation of the dose delivered in the radiotherapy treatment plan. However, the normal cells generally have a better recovery mechanism than the cancerous cells [3 - 5].

Figure 3(a) and 3(b) shows the plots of percentage depth dose of 6 MV and 15 MV photon energies at nominal distance of 100 cm and at extended SSD of 100, 120, 130, and 140cm. The Elekta NHA SLi 1998 linear accelerator was used to measure the percentage depth dose at 100 cm SSD for 6 MV and 15 MV photon energies. The Mayneord factor was used to determine the percentage depth dose at 110, 120, 130, and 140cm.

Figure 3(c) compare calculated percentage depth dose at extended distances (SSD) ranging from 110 cm to 140 cm for 6 MV and 15 MV energies. Surface dose and D_{max} for 6 MV are found to be 65.3% and 1.62 cm, respectively and for 15 MV are 46.5% and 2.65 cm, respectively. At depth beyond D_{max}, the PDD curve deviated from each other with the highest at 140 cm SSD, and lowest at 100 cm SSD.

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This implies that the Mayneord factor is in good agreement with the literature [4 - 6].

The calculated PDD at extended SSD plots seem to start at same point through D_{max} but however deviated from each other with an increase in depth. This is due to the deflection of low energy photons resulting in less scatter of photon and allowing high energy photon to interact as the SSD is increased.

Conclusion

The process of commissioning a linear accelerator (LINAC) for clinical use includes comprehensive measurements of dosimetric parameters. It is a process where a full set of data is acquired that will be used for patient treatment. This, however, is limited to 10 x 10 cm^2 field size and at 100 cm SSD. The measured PDD values have been shown to have good agreement with those in published literature. The D_{max} and D_{10} for 6 MV and 15 MV photon beam were found within the limit mentioned in the IEC 60976 scale. The calculated PDD values at extended SSDs are considered to be suitable for clinical use at all clinically relevant depths and field sizes.

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Conflict of Interest: Nil

Reference

1. Murshed Hossain, Ying Xiao, and M. Saiful Huq. An investigation of a model of percentage depth dose for irregularly shaped fields. *International Journal of Cancer*, 2001; 96:140-145.

2. Michael J. Price, Kenneth R. Hogstrom, John A. Antolak, Allen White, Charles D. Bloch, and Robert A Boyd. Calculating percent depth dose with the electron pencil-beam redefinition algorithm. *Journal of Applied Clinical Medical Physics*, 2010; (2): 61-76.

3. Charles Packard. Calculation of percentage depth dose. Radiology. Radiology Society of North America. 82nd scientific assembly and annual meeting, Chicago, illiois. 2009; 130 (5): 44 - 48

4. International Commission on Radiological Units and Measurement, Determination of absorbed dose in a patient irradiated by beams of x or gamma rays in radiotherapy procedures. *ICRU Report No. 35. Publication 24 of ICRU*, Bethesda, MD 1976; (4): 337-345

5. International Electrotechnical Commission. Medical Electrical Equipment, Dosimeters with ionization Chambers as used in Radiotherapy, *Standard IEC-60731, IEC Publication*, Geneva, Switzerland 1989; (2): 134-136.

6. Jaffray D.A., Lindsay. P.E., Brock. K.K., Deasy. J.O., and Tome. W.A. Accurate accumulation of dose for improved understanding of radiation effects in normal tissue. *International Journal of Radiation Oncology in Biology and Physics*, 2010; 76(10): 135– 139.

7. Podgorsak E.B. Radiation Oncology Physics: A handbook for teachers and students. *International Atomic Energy Agency, Vienna IAEA*. 2005. ISBN: 92-0-107304-6. Pp. 413–446.

8. Spunei M., Mihai. M., and Malaescu. I. Experimental results in percentage depth dose (PDD) determination at the extended distance. *Romanian Reports in Physics* 2013; 66(1): 58-63

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