

## Percentage Discrepancies Assessment Between Measured and Calculated Behaviour of Percent Depth Dose in External Beam Radiotherapy

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**Abstract.** The aim of this study was to calculate percentage discrepancies (PD) of the measured and calculated percentage depth doses (PDDs) values. The 6 MV photon beam produced by the Varian linear accelerator 2100 C/D was used in this study. PDDs, tissue maximum ratios (TMR) and phantom scatter factor ( $S_p$ ) were measured using the PTW 31006 ionisation chamber in water phantom. PD between PDD values of the measured and calculated was ranging between 0.30% and 2.38%. Percentage discrepancies were also found higher against 20 cm depth in water for (20×20) cm<sup>2</sup> field size. These discrepancies should be taken into account, while delivering any medical dose in radiation therapy centers.

**Keywords:** percentage depth dose, percentage discrepancies, ionisation chamber

### Introduction

Medical linear accelerators are playing important role in radiation centres all over the world. Specific radiation dose is applied to cancer patients for curative as well as palliative treatment. However, for each case the prescribed dose ought to be delivered accurately both in quantity and quality. Over or under-dosage could be harshly destructive to the patient or may lead to unwanted outcomes. For accuracy concerns supercomputers have been introduced in radiation therapy centres. These computers exploit commercial programmes and algorithms for the management of model dose distributions within the irradiated part of the patient. In order to attain precised output from these modern facilities, they have to be fed with exact beam data measured from the modern treatment machines. Hence, medical physicists are more concerned about quality assurance of accelerators and consistency of the radiation measurements. These measurements are based on daily, monthly and yearly procedures to assure accurate delivery of dose to patient. International Associations and Agencies of Physicists in Medicine (such as AAPM and IAEA) produce updated publications of acceptable tolerance for mechanical actions and radiation field output. These publications are found to promise accomplishment of immense accuracy of dose delivery to the right body volume (IAEA, 2000; Peter *et al.*, 1999).

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Though, measurements of percentage depth dose (PDD) could be exaggerated by factors, which are not commonly taken into account. These contains movement of water during PDD or beam profile measurements, predominantly when measuring surface dose and physical dimensions of the measuring apparatus such as the ionisation chamber or TLD. Direct formulas can also be sometime used to determine vital radiation quantities. These formulas can be used when the other variable quantities are known. Monte Carlo simulations could be practical in calculating the amount of certain quantities such as PDD, beam profiles; flux and dose delivery to definite position in the treatment room or within the patient (Rogers, 2002; Ahnesjo and Aspradakis, 1999; Bloch and Altschuler, 1995).

Percentage discrepancies may exist due to some properties of measuring devices or attributed to some issues such as movement of water during measurements. It is not understandable why such discrepancies subsist. Exactness in manufacturing may also affects on accuracy (Sameer, 2007). Percentage discrepancies (PD) have been calculated between measured and calculated PDDs at different field sizes and depths. The calculated PDDs were worked out by using formula, with constant SSD. Phantom scatter factor and tissue maximum ratios (TMR) were measured and used in the formula to evaluate the calculated PDDs values. The PD and PD gradient values were computed between the calculated

and measured PDDs for 6 MV energy. This work provides an alternative approach to radiation oncology physicists about the necessity of quality assurance and this ultimately improves the quality of the treatments.

**Materials and Methods**

Since the water behaviour is quite similar with human body, therefore, beam profile and PDDs are usually measured in water phantoms to resemble a patient after introducing correction factors for temperature and pressure. This study was carried out on a PTW scanning water phantom (40×40) cm<sup>2</sup> with ionisation chamber of active volume of 0.5 cm<sup>3</sup>. The ionisation chamber was installed on the moveable sampling holder of the phantom. Another chamber was fixed on the phantom as a reference chamber. The Varian medical accelerator 2100 C/D having energy of 6 MV was used. The field chamber was moved when the radiation was “ON” and reference chamber was fixed. The output was read out on the electrometer and then the ratio of both chambers’ reading was used to make the PDD or dose profile data. The peak absorbed dose on the central axis occurs at the end of build up region. By definition (Birgani and Karbalaee, 2009) the PDD is:

$$PDD = \frac{D_d}{D_{max}} \dots\dots\dots(1)$$

where:

$D_d$  = dose at depth;  $D_{max}$  = depth of maximum dose.

Dosimetry studies show that the PDD initially increases rapidly until the depth of the maximum dose is achieved. Beyond this the dose decreases slowly with depth. This study was confirmed by calculating the PDD using the formula of Khan (2010).

$$P(d,r,f) = TMR(d,r_d) \left( \frac{f+t_o}{f+d} \right)^2 \left( \frac{S_p(r_d)}{S_p(r_{t_o})} \right) \cdot 100 \dots\dots\dots(2)$$

where:

$TMR(d, r_d)$  = measured tissue maximum ratio;

$f$  = SSD;  $r_d = r \cdot \left( \frac{f+d}{f} \right)$ ;  $r_{t_o} = r \cdot \left( \frac{f+t_o}{f} \right)$ ;  $d$  = depth;  $r_d$  = field size at reference depth;  $t_o$  = reference depth at maximum dose;  $S_p(r_d)$  = phantom scatter factor at reference depth  $d$ ;  $S_p(r_{t_o})$  = phantom scatter factor at reference depth at maximum dose.

TMR is used for high energy photon beams. PDDs, TMR and  $S_p$  values were measured by fixing the reference depth at 1.5 cm of ionisation chamber in water phantom.  $S_p$  was found by small diameter chamber using measured

PDD data. Then these measured values of TMR,  $S_p$  and PDDs were used in formula containing equation (2) to calculate PDDs.

**Results and Discussion**

Table 1 reveals the  $S_p$ , TMR, PDDs values, which were measured using the arrangement as show in Fig. 1. These TMR,  $S_p$ , PDDs values were used in formula (2) and new PDDs were calculated. Table 2 shows the measured values and Table 3 shows the calculated values at some selected depths in water. PD was found between the measured and calculated PDDs.

Percentage discrepancies (PD) between PDD values for measured and calculated values are shown in Table 2 at same depth and field size. Taking PDD measured values as a reference; PD values were calculated using the following formula (Sameer, 2007).

$$PD = \frac{PDD_{Calculated} - PDD_{Measured}}{PDD_{Measured}} \times 100\%$$

The uppermost PD value was found in Fig. 2 and by Table 2 at (15×15) cm<sup>2</sup> field size, while the minute value was observed at 1.5 cm depth for both the (20×20) cm<sup>2</sup> and (25×25) cm<sup>2</sup> field sizes. Table 3 illustrates the maximum PD value in this study at 6MV was 2.38% at depth 20 cm with (15×15) cm<sup>2</sup> field size, while minimum value (0.30%) with the same field size was found at 1.5 cm near the water surface.

Figure 2 demonstrates the relationship between PD values in Table 2 and field size at each selected depth in water at 6 MV.

Figure 2 confirms the values of Table 2 i.e., the PD values improve with depth in water and depreciate with field size. PD gradient shows an increment or decrement in values at each step during delivery of doses. A medical physicist must know the change in dose at every step, while delivering the accurate doses to patients. The maximum PD gradient between these values can be found as:

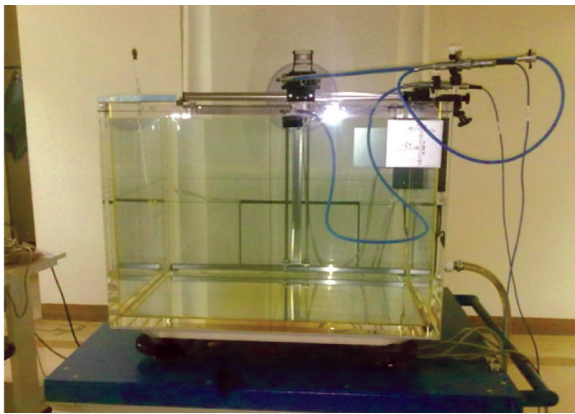
$$= \frac{2.38 - 0.3}{15} = 0.1386 \text{ cm}^{-1}$$

This shows a 0.1386% increment in PD occurring from every 1 cm from  $D_{max}$  to depth of 20 cm that correspond to maximum PD gradient. Similarly, the minimum PD gradient was found at field size of 20×20 cm<sup>2</sup> as calculated by:

$$= \frac{0.22 - 0.1}{20} = 0.006 \text{ cm}^{-1}$$

**Table 1.** Measured values of TMR, Phantom scatter factor and others at certain depths and field sizes for 6 MV photon beam

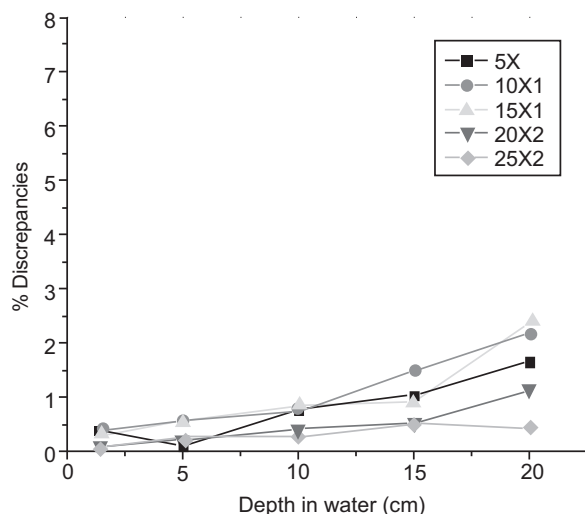
Field size (r)	Depth (d)	TMR	$r_d$	$S_p(r_d)$	$r_{t0}$	$S_p(r_{t0})$	Calculated PDD	Measured PDD
5×5	1.5	0.992	5.075	0.968	5.075	0.968	99.2	99.6
	5	0.913	5.25	0.968	5.075	0.968	85.3	85.7
	10	0.754	5.5	0.968	5.075	0.968	64.1	64.6
	15	0.611	5.75	0.968	5.075	0.968	47.5	48
	20	0.499	6	0.974	5.075	0.968	35.4	36
10×10	1.5	0.993	10.15	1	10.15	1	99.3	99.7
	5	0.929	10.5	1	10.15	1	86.8	87.3
	10	0.797	11	1.005	10.15	1	67.5	68
	15	0.658	11.5	1.005	10.15	1	51.0	51.8
	20	0.545	12	1.01	10.15	1	38.6	39.5
15×15	1.5	0.995	15.225	1.022	15.225	1.022	99.5	99.8
	5	0.938	15.75	1.022	15.225	1.022	87.6	88.1
	10	0.816	16.5	1.022	15.225	1.022	69.4	70
	15	0.692	17.25	1.022	15.225	1.022	53.9	54.4
	20	0.581	18	1.035	15.225	1.022	41.0	42
20×20	1.5	0.998	20.3	1.035	20.3	1.035	99.8	99.9
	5	0.944	21	1.035	20.3	1.035	88.2	88.4
	10	0.83	22	1.035	20.3	1.035	70.6	70.9
	15	0.713	23	1.035	20.3	1.035	55.5	55.8
	20	0.611	24	1.041	20.3	1.035	43.4	43.9
25×25	1.5	0.996	25.375	1.041	25.375	1.041	99.6	99.7
	5	0.947	26.25	1.041	25.375	1.041	88.4	88.7
	10	0.84	27.5	1.041	25.375	1.041	71.5	71.7
	15	0.731	28.75	1.043	25.375	1.041	56.8	57.1
	20	0.629	30	1.043	25.375	1.041	44.9	45.1

**Fig. 1.** Set-up of water phantom and ionisation chamber.**Table 2.** Calculated PD values between measured and calculated values for 6MV photon beam

Depth in water (cm)	Field size (cm×cm)				
	5×5	10×10	15×15	20×20	25×25
1.5	0.40	0.40	0.30	0.10	0.10
5	0.11	0.57	0.56	0.22	0.27
10	0.77	0.73	0.85	0.42	0.27
15	1.04	1.5	0.91	0.53	0.52
20	1.66	2.2	2.38	1.13	0.44

Table 3 summarizes the conspicuous statistical values for PD and PD gradient.

Error range between maximum and minimum PD was 2.28 and between PD gradient was 0.1326 by origion Pro-7 software.



**Fig. 2.** Variation of PD with depth in water at 6 MV.

**Table 3.** Statistical summary of PD and PD gradient values

	PD	PD gradient (cm <sup>-1</sup> )
Maximum	2.38	0.1386
Minimum	0.10	0.006
Mean	1.24	0.0723

Previously, Sameer (2007) reported for comparative study of measurements. The PDD measurements were done between two different medical linear accelerators and the PD values were calculated. It was concluded that these discrepancies should be considered, while, delivering dose to the cancer patient.

## Conclusion

Percentage discrepancies (PD) were found out between measured and calculated values. PD describes how much calculated values resemble to measured values. For the same depth and field sizes, PDDs were found minute different for both the measured and calculated values at 6 MV. PD ranged between a maximum of 2.38 and minimum of 0.010 with mean value of 1.24 for 6 MV. It may depend on some factors such as properties of measuring devices and movement of

water during measurements. PD gradients were also calculated and found ranging between a maximum of 0.1386 cm<sup>-1</sup> and a minimum of 0.006 cm<sup>-1</sup> with a mean value of 0.0723 cm<sup>-1</sup> for 6 MV.

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