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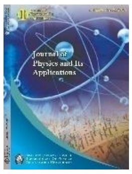

Comparison of Percentage Depth Doses with the Published Data for Co-60 Radiotherapy Machine at a Regional Cancer Hospital

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ABSTRACT

In external beam radiation therapy, the percentage depth dose (PDD) is a main factor for estimation of patient's dose and dose distribution in target volume, therefore its accurate estimation is important. The purpose of this article is to compare PDDs with the published PDDs of different authors along central axis at different depths and field sizes for cobalt-60 (Co-60) radiotherapy machine at a regional cancer hospital Pakistan. A dedicated water phantom was used for estimation of PDDs at different depths and different field sizes, for Theratron phoenix Co-60 machine. It was observed that for 10×10 cm^2 filed size of Co-60 beam mean percent variation in measured PDDs and published PDDs by different authors was -0.29% to 1.13%, which was within acceptable limit of ± 2%. However, for one author who used semi-empirical equation for PDDs calculation, the mean percent variation between measured PDDs and that of the author was -3.23%, 4.69% and 5.88% for 10×10 cm^2, 25×25 cm^2 and 30×30 cm^2 field sizes of Co-60 beam respectively, which were within acceptable limit of ±10%. A noticeable increase in PDDs was observed with increase of the field size at given depth which shows obvious contribution of secondary scattered radiation. Also measured PDDs were well matched with that of published PDDs of most of the authors i.e. ± 2%, but the measured PDDs were moderately matched with that of PDDs for only one author for some field sizes and some depths i.e. ±10%, which need to be rectified by taking more such data.

1. Introduction

According to modern practice, approximately 50% of the patients should have received radiotherapy in cancer management, at least one time during cancer treatment or palliation [1]. The purpose of radiotherapy is to deliver the maximum dose to the tumor and minimum dose to the surrounding tissues [1, 2]. Percent depth dose (PDD) is a significant parameter of treatment planning for cancer patients treating with radiations accurately [3]. For dosimetry of teletherapy units, homogenous water phantom should be used [3-5] in order to estimate PDDs, because these estimations are not possible in real patients [3]. They are then used in treatment planning system (TPS), to calculate the radiation absorbed dose for the real cancer patients [3, 6, 7]. Radiation absorbed dose inside the body depends on various parameters, such as the field size, beam energy, source to skin distance (SSD), depth [3, 5, 8, 9], angle of beam incidence, beam-modifying devices PDDs [9]. In radiotherapy greater accuracy and precision is highly demanded, because a very small variation in radiation dose has greater effect on the probability of cancer cure. Various studies suggested that variation of 5% in radiation absorbed dose resulted in 10-20% change in tumor control and 20-30% change in normal tissues complications [10, 11]. The probability of cancer cure may be changed, with an irreversible damage of 2-3 times with respect to variation of 10-15% radiation absorbed dose delivery to the cancer patients [3]. Therefore the practices of radiation therapy is very much susceptible in scheming the dose conveyed to tumor target volume i.e. there is ± 5% allowable change from the prearranged tumor dose and reducing or shielding the critical organs [3, 12]. The correctness of beam data acquisition is very important for quality assurance of a radiotherapy equipment, because error in the data will impact every patient treated with the equipment [13]. In radiotherapy of cancer management PDDs give information of radiation absorbed dose at specific depth inside the tumor [14, 15], which is very necessary. Therefore, the purpose of the study is to measure and verify PDDs at various depths and for various field sizes and compare with other published PDDs [3, 4, 16-18], to authenticate the quality assurance of Co-60 radiotherapy machine at a regional cancer hospital in the northern part of Khyber Pukhtunkhwa (KPK) province of Pakistan.

2. Methods

The PDDs were measured for different field sizes of 10×10 cm^2, 25×25 cm^2, 30×30 cm^2 and for different depths (0.5 cm & 1-27 cm) with 1cm interval of gamma radiations produced by Theratron phoenix Co-60 machine installed at Swat Institute of Nuclear Medicine, Oncology & Radiotherapy (SINOR) cancer hospital, Swat, KPK Pakistan. The study was conducted to verify PDDs of Co-60 machine for different filed sizes and different depths, which is a part of quality assurance program (QAP) for accurate and precise treatment delivery in radiotherapy. The PDDs were estimated in sun corporation dedicated water phantom with farmer type ionization chamber. The ionization chamber was brought to different depths in the water phantom, model 1233, with the help of sun nuclear corporation (SNC) computer software. The hand control unit (HCU) was used for the fine adjustment of water phantom under the Co-60 head. The spirit level was used for the leveling of water surface. The GTD 1100 barometer was used to measure the atmospheric pressure. The GTH 175/pt thermometer was used for measurement of temperature in the water. The PDDs were measured using equation-1, at different depths and field sizes inside the water phantom[15] with fixed SSD of 80 cm for Co-60 radiotherapy machine [6].

$$PDD = \frac{D}{D_m} \times 100\% \quad (1)$$

Where PDD is percentage depth dose measured in our study, D and D_m are dose at depth d and dose at depth d_{max} respectively.
The exposure time for all readings, gantry & collimator angles were set according to protocol of international atomic energy agency(IAEA) TRS-398 [3, 19]. The measured PDDs were compared with published data of different authors for different field sizes of Co-60 beams and percent variations between measured PDDs and that of published data [3, 4, 16-18] were calculated by equation-2.

$$P_V = \frac{M_V - A_V}{A_V} \times 100\% \quad (2)$$

Where P_V is percent variation, M_V is the measured PDD and or A_V is the published PDD from other references, as published data [3, 4, 16-18]. In this study the measured PDDs in equation-1 were compared with the results of Memon et al [3], T. Jordan (BJR Supplement) [18], S. A. T. Abdalla [16], Praveen Kumar [4] and Sadiq R. Malik et al [17].

3. Results and Discussion

PDDs were measured in SINOR cancer hospital, Swat, KPK, Pakistan, for which the temperature was 26.3 ^{0}C and the atmospheric pressure was 903 KPa during the data acquisition. The PDDs measured in this study and published PDDs by authors [3, 4, 16-18], as a function of depth in water for field size of 10×10 cm^2 is shown in Figure-1. [17] of the published data, while for theoretical data the acceptable limit should not more than ± 20% [21]. In this study the PDDs were measured and compared with five authors [3, 4, 16-18], among whom four authors [3, 4, 17, 18] have taken experimental data, but one author [16] has applied semi-empirical equation for taking PDDs. In this study the measured PDDs were within acceptable limit of ± 2% of published data of the four authors [3, 4, 17, 18] and ± 10% of published data of one author [16]. PDDs verification is the prime responsibility of medical physics division to ensure accurate radiation treatment dose delivery to the

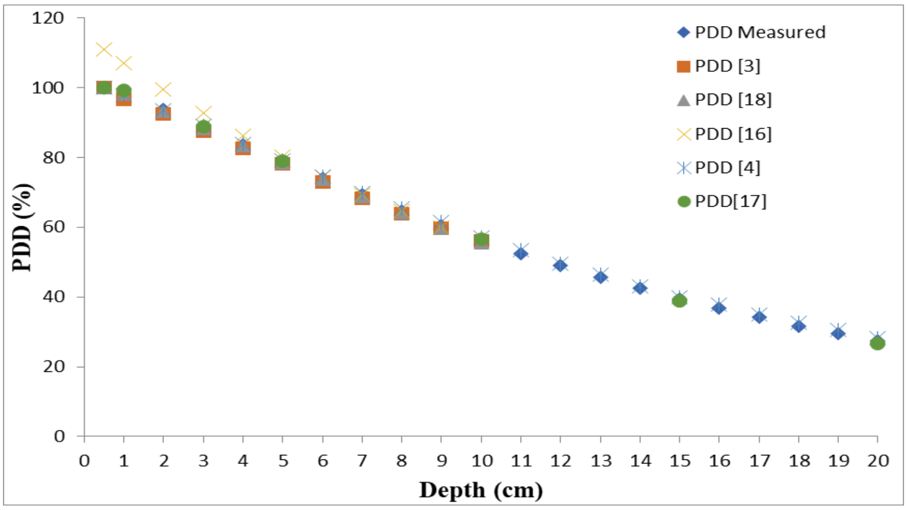

Fig 1. Comparison of measured PDDs with the published PDDs by authors [3, 4, 16-18] for field size of 10×10 cm^2.

In radiotherapy, if the uncertainties in PDDs are reduced, the accuracy in absorbed dose to tumor will be considerably improved and organ at risk (OAR) will be accurately spared [20]. For experimental data the measured PDDs for Co-60 machine should be within acceptable limit of ± 2%

cancer patients, as it is a significant part of strict quality assurance program in radiotherapy. The measured PDDs values for field size of 10×10 cm^2 in comparison with published PDDs by different authors [3, 4, 16-18] for 0.5cm and 1-20 cm depths with 1 cm interval are further shown in Table-1.

Table 1. Comparison of measured PDDs with published data of references [3, 4, 16-18] for 10×10 cm^2 field size.

Sr. No.	Depth (cm)	PDD Measured	PDD [3]	PDD [18]	PDD [16]	PDD [4]	PDD[17]
1	0.50	100	100.00	100.00	110.9	100	100
2	1.00	98.1	96.62	98.10	107	97.9	99.1
3	2.00	93.7	92.36	93.30	99.5	93.5	-----
4	3.00	88.7	87.64	88.30	92.6	89	88.7
5	4.00	83.7	82.57	83.40	86.1	83.9	-----
6	5.00	78.8	78.18	78.50	80.1	79.2	78.8
7	6.00	73.9	72.97	73.60	74.5	74.5	-----
8	7.00	69.3	68.38	68.80	69.3	69.8	-----
9	8.00	64.7	63.85	64.10	64.5	65.3	-----
10	9.00	60.5	59.59	59.70	60	61.4	-----
11	10.00	56.4	56.08	55.60	-----	57.1	56.6
12	11.0	52.5	-----	-----	-----	53.4	-----
13	12.0	48.9	-----	-----	-----	49.6	-----
14	13.0	45.6	-----	-----	-----	46.4	-----
15	14.0	42.4	-----	-----	-----	43.1	-----
16	15.0	39.4	-----	-----	-----	39.8	38.8
17	16.0	36.8	-----	-----	-----	37.8	-----
18	17.0	34.1	-----	-----	-----	35	-----
19	18.0	31.7	-----	-----	-----	32.5	-----
20	19.0	29.5	-----	-----	-----	30.5	-----
21	20.0	27.4	-----	-----	-----	28.2	26.6

Percent variations, P_{V1}, P_{V2}, P_{V3}, P_{V4}, P_{V5} for field size of 10×10 cm^2 were also calculated between measured PDDs and PDDs by different authors [3, 4, 16-18].

It was obsorved that for 10×10 cm^2 Co-60 beam, mean value of percent variation, P_{V1}, P_{V2}, P_{V3}, P_{V4}, P_{V5} between measured PDDs and published PDDs was 1.13 (0, 1.53)% , 0.59 (0, 1.44)%, -3.23 (-9.83, 0.83)%, -1.29 (0.78, 0.81)% and 0.25 (-1.44, 3.01)% respectively as shown in Table-2 and Figure-2.

Table 2: Percent variations between measured PDDs and PDDs by different authors [3, 4, 16-18], for 10×10 cm^2 field size of Co-60 beam.

Depth (cm)	P_{V1} [3]	P_{V2} [18]	P_{V3} [16]	P_{V4} [4]	P_{V5} [17]
0.50	0	0	-9.83	0	0
1.00	1.53	0	-8.32	0.20	-1.01
2.00	1.45	0.43	-5.83	0.21	-----
3.00	1.21	0.45	-4.21	-0.34	-1.44
4.00	1.37	0.36	-2.79	-0.24	-----
5.00	0.79	0.38	-1.62	-0.51	0.03
6.00	1.27	0.41	-0.81	-0.81	-----
7.00	1.35	0.73	0	-0.72	-----
8.00	1.33	0.94	0.31	-0.92	-----
9.00	1.53	1.34	0.83	-1.47	-----
10.00	0.57	1.44	-----	-1.23	-0.35
11.0	-----	-----	-----	-1.69	-----
12.0	-----	-----	-----	-1.41	-----
13.0	-----	-----	-----	-1.72	-----
14.0	-----	-----	-----	-1.62	1.55
15.0	-----	-----	-----	-1.01	-----
16.0	-----	-----	-----	-2.65	-----
17.0	-----	-----	-----	-2.57	-----
18.0	-----	-----	-----	-2.46	-----
19.0	-----	-----	-----	-3.28	-----
20.0	-----	-----	-----	-2.84	3.01

	Average =1.13	**Average = 0.59**	**Average = -3.23**	**Average = -1.29**	**Average = 0.25**
	Min = 0	**Min = 0**	**Min = -9.83**	**Min = 0.78**	**Min = -1.44**
	Max = 1.53	**Max = 1.44**	**Max = 0.83**	**Max = 0.81**	**Max = 3.01**

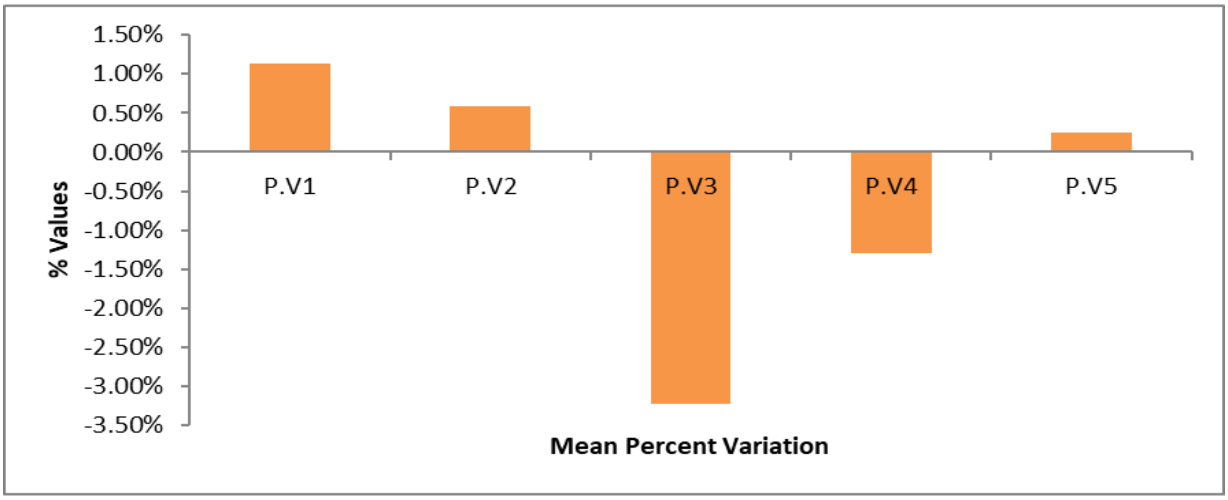

Fig 2. Mean percent variations between measured values and PDDs by different authors [3, 4, 16-18] for 10 ×10 cm² field size of Co-60 beam.

The mean percent variations, P_{V1}, P_{V2}, P_{V4}, P_{V5} were well below acceptable limit of ±2%, as these authors have measured PDDs experimentally. However the percent variation, P_{V3} value was comparatively high i.e. within ±10% of the published data. The reason for this high variation is that this author [16] have calculated PDDs by using semi-empirical equation.

The measured values of PDDs were also compared with that published data [16] for field sizes of 25×25 cm² and 30×30 cm² field sizes of Co-60 beams at depth of 0.5 to 27 cm, as shown Table-3 and Figure-3.

Table 3: Comparison of measured PDDs with published data of Abdalla, S.A.T [16] for field sizes of 25×25 cm² and 30×30 cm².

S. #	Depth	Measured PDD	PDD [16]	Measured PDD	PDD [16]
Depth in cm		**25 ×25 cm² Field Size**		**30 ×30 cm² Field Size**	
1	**0.5**	100	100.7465	100	100
2	**1**	98.4	100	98.5	98.529
3	**2**	94.5	94.03	94.7	94.118
4	**3**	90.3	89.552	90.5	89.706
5	**4**	86	85.075	86.3	85.294
6	**5**	81.7	80.597	82.1	80.882
7	**6**	77.5	76.119	78.1	76.471
8	**7**	73.3	71.642	73.9	72.059
9	**8**	69.5	67.164	70.1	67.647
10	**9**	65.6	64.179	66.3	64.706
11	**10**	61.9	59.701	62.6	60.294
12	**11**	58.3	56.716	59.1	57.353
13	**12**	55	53.73	55.8	54.412
14	**13**	51.8	50.746	52.8	50
15	**14**	48.7	46.269	49.8	47.059
16	**15**	45.9	44.776	46.9	44.118
17	**16**	43.2	41.791	44.2	42.647
18	**17**	40.5	38.806	41.6	38.235
19	**18**	38.1	35.821	39.2	36.765
20	**19**	35.8	32.836	36.9	33.824
21	**20**	33.5	31.343	34.7	32.353
22	**21**	31.65	29.851	32.75	29.412
23	**22**	29.8	26.866	30.8	27.941
24	**23**	28	25.373	29.05	25
25	**24**	26.2	23.881	27.3	25
26	**25**	24.7	22.388	25.75	22.059
27	**26**	23.2	20.896	24.2	20.588
28	**27**	21.9	19.403	-----	-----

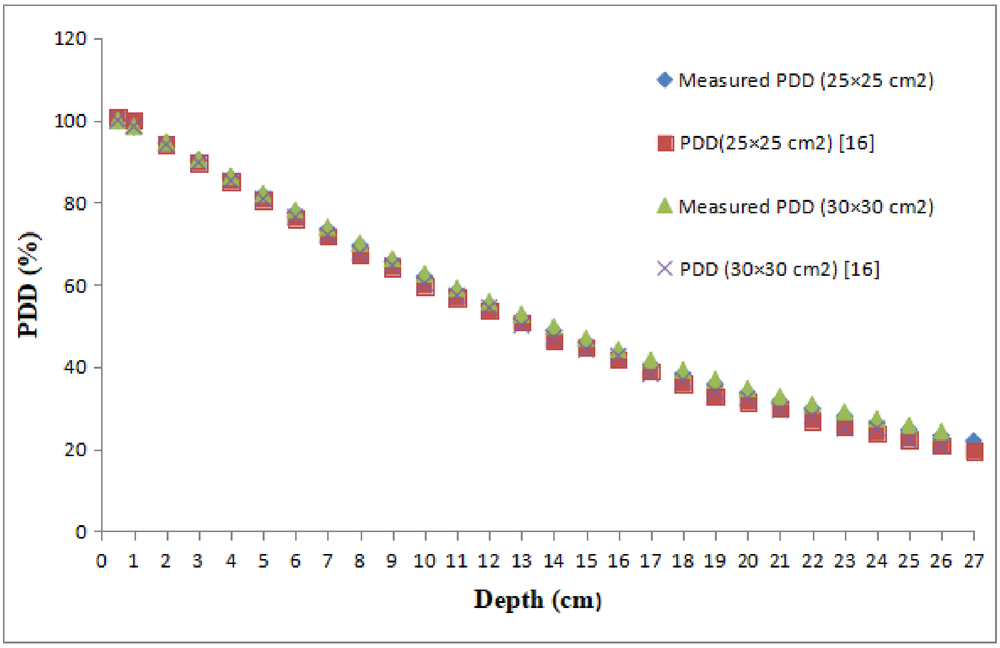

Fig 3. Comparison of measured PDDs with the published PDDs [16] filed sizes 25×25 cm² and 30×30 cm².

The mean percent variations (P_{V6} & P_{V7}) ± SD between measured PDDs and that of the author [16] was 4.69 ± 4.01 with a range of (-1.60, 12.87) and 5.88 ± 5.10 with range (-0.03, 17.54) for field sizes of 25×25 cm² and 30×30 cm² respectively as shown in Figure-4. It was observed in Figure-4 that percent variations, P_{V6} & P_{V7} between measured PDDs and published PDDs [16] for field sizes of 25×25 cm² and 30×30 cm² increases linearly with increase in depth. It was observed that the PDDs were increased with respect to increase in field size due to higher scattered radiation, while keeping depth constant. The relative difference in measured PDDs with change in field size was observed to be less than 5%. The relative difference in measured PDDs was observed higher at higher depths due to higher irradiated volume, while keeping field size constatnt and vice versa, as demonstrated in Table-1& Table-3.

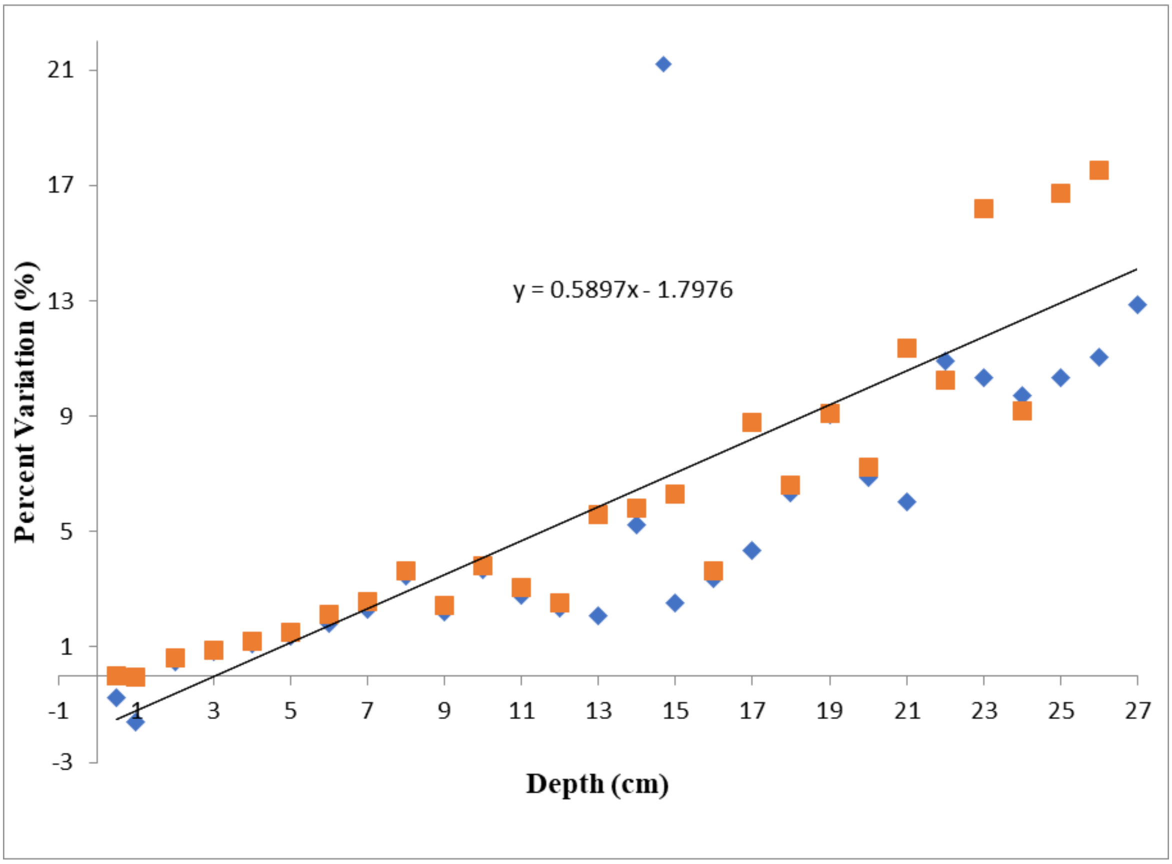

Fig 4. Graph between depth (cm) and percent variations, P_{V6} & P_{V7} between measured PDDs and published PDDs [16] for field sizes of 25×25 cm² and 30×30 cm² respectively.

This study was done at SINOR cancer hospital, Swat Pakistan. Pakistan is a developing country, though radiotherapy is switching to advanced techniques like IMRT, IGRT etc. but still in comparison with advanced countries greater radiotherapy cases are treating with Co-60 machine. Therefore in developing countries Co-60 machines occupy an important place in radiotherapy field [13, 22] because of their significantly lower wealth and installation cost, lower service and maintenance cost, lesser dependence on reliable electrical power, simplicity of design and ease of operation[22]. According to the World Health Organization (WHO) approximately 750 of 3125 (24%) reported unfavorable cases in radiation oncology originated from the commissioning stage. Beam data acquisition (dosimerty) is a significant step in the commissioning process and modeling. Errors occurred during beam data acquisition and modeling are very danger as it will affect every patient treated on a given machine. Therefore, it is essential this procedure should be accurate and error free [13]. Direct measurement of radiation absorbed dose in patient is impossible, so indirect measurement in tissue equivalent materials i.e. water phantom is used for such data acquisition like PDDs [23]. This type of data from the literature is not appropriate, because literature values are normally the mean of measurements for unlike makes of the similar radiation facility [6]. Therefore such data should be taken for Co-60 teletherapy unit in every institute and should be compared with the published data [16]. In this study PDDs were calculated for along central axis of the beam for Co-60 for different depths and different field sizes by using 1D water phantom and farmer type ionization chamber in order to ensure accurate dose delivery to the cancer patients. The measured values of PDDs were comparable of the published data [3, 4, 16-18], even some of these used advanced technique like Monte Carlo simulation code of EGSnrc and 3D Phantom RFA300 water phantom and ion chamber FC-65[17]. This study shows that the feasibility of gathering Co-60 beam data by dedicated water phantom and automated couch movements with the objective to maximize the cost effectiveness in resource limited clinical setting. The agreement between the measured data and that of [16] at some depths and some larger field sizes was moderate. The reason is that in, the author [16] has claimed that semi-empirical equations used in his study fits for small field sizes, but at greater field sizes there are little deviations. However still more data from different institutes must be taken and published in order to confirm the PDDs for various field sized and depths, which will further strengthen to resolve the mentioned moderate agreement.

4. Conclusions

A noticeable increase in PDDs was observed with increase in field size at given depth which shows obvious contribution of secondary scattered radiation to the primary beam of photon gamma radiations. The percent difference in measured PDDs with change in field size, while keeping depth constant was observed to be less than 5%. However, this difference in measured PDDs was observed higher at higher depths due to higher irradiated volume, while keeping field size constant and vice versa. Also measured PDDs were well matched with the published PDDs of most of the authors i.e. ± 2%, but the measured PDDs were moderately matched with that of PDDs for only one author for some field sizes and some depths i.e. ±10%, which need to be rectified by taking more such data.

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