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Estimation of midpoint dose for cervical cancer patients using EPID

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Abstract

Purpose: To estimate the midpoint dose delivered to cervical cancer patients treated by conventional technique using Electronic Portal Imaging Device (EPID).

Materials and Methods: Clinac 2100 equipped with aS500 EPID was used in this study. A methodology was developed to generate a Gy/Calibration Unit (CU) look up table for the determination of midpoint dose of patients. 25 patients of cervical cancer were included in this study and the delivered dose to the midpoint of the patients was estimated using EPID. The deviation between the prescribed and the measured dose was calculated and analysed.

Results: EPID showed a linear response with increase in Monitor unit and the Gy/CU look up table was validated for different field sizes and depth. 250 fields were measured for 25 patients, 10 measurements per patient, weekly once and for 5 weeks. The results show that out of 250 measurements, 98% of the measurements are within ±5% and 83.2% are within ±3% for with a standard deviation of 1.66%.

Conclusion: The outcome of this study proves the efficacy of this methodology for the estimation of midpoint dose using EPID with minimal effort, time and without any inconvenience to the patients unlike other in-vivo dosimeters.

Key words: cervical cancer; EPID; in-vivo dosimeter; ion chamber.

Introduction

Radiotherapy is an important modality of treatment in the management of majority of cancer patients. The success of radiotherapy depends on the accurate dose delivery to the tumour. The International Commission on Radiation Units and Measurements (ICRU report 24) has recommended a tolerance limit of ±5% in the radiation dose delivery. Well-developed national and international protocols are available for mechanical, dosimetric quality assurance of the radiation delivering equipments and its calibration [1], but there is no stringent quality assurance methods for the estimation of the radiation dose actually delivered to the patients. In-vivo dosimetry is an important tool to assure /estimate that the prescribed dose is delivered to the tumour. In-vivo Dosimetry is the measurement of dose delivered to the target volume in radiotherapy by either direct or indirect means [2]. This is usually done by placing the detector in the body cavities or in the entrance or exit skin surface. Entrance or exit dose measurements are usually carried out and the target dose is calculated from it. The measurement of target dose has always been the area of interest and various methods are tried for its direct measurement or estimation. Diodes, Thermoluminescent Dosimeter (TLD), Metal Oxide Semiconductor Field Effect Transistor (MOSFET) detectors, gel/plastic scintillators, Radio graphic and Radio chromic films have been commonly used for In-vivo dosimetry [3].

Electronic Portal Imaging System, initially designed for positional verification, has also attracted many researchers to exploit its use as in-vivo dosimeter [4]. EPID gathers information about beam fluence in any given condition, which is then converted into dose. It has got the dose information for the entire plane unlike diodes or TLD, which are the commonly used in-vivo dosimeters. Its main advantages are fast image acquisition, high resolution and digital format [4]. Various models or algorithms have been developed to estimate the dose at isocentre or any other reference point or plane by back projection technique. We have developed a simple methodology to estimate the dose at midpoint of the patient using transit EPID images.

In spite of technical advancements in the field of radiotherapy, conventional 2-Dimensional treatment is being used for a majority of patients and the prescribed dose delivery to the patient is rarely verified in Indian scenario. Cervical cancer is the common malignancy among women in developing countries [5] and conventional two field technique is used for most of the patients and hence an attempt has been

made in this work to measure and compare the midpoint dose with the prescribed dose for cervical cancer patients by measuring the exit dose for each portals, using electronic portal imager , portal dosimetry software and the generated Gy/CU look up table.

Materials and Methods

Linear accelerator (Varian Clinac 2100C) equipped with Electronic Portal Imaging Device (EPID aS500) along with Portal Dosimetry software was used in this study. In order to use the portal dosimetry software in Eclipse Treatment Planning System, the PDIP algorithm was commissioned as per the Varian Protocol. Portal Dosimetry software measures the dose in terms of Calibration Unit (CU) which is a unit that is specific to Varian's Portal Dosimetry. The calibration is performed so that 100 MU delivered with a 10×10 cm^2 field size is normalized to a reading of 1 CU if the EPID is positioned at isocentre distance (SDD = 100 cm).

Linearity of EPID with MU

The CU values were acquired without any attenuating medium between the EPID and the LINAC head for the field size of 10 x 10 cm^2 and EPID distance of 150 cm. The linearity of CU with MU was analysed for 1 to 500 MU for 15 MV photon beams using graphical method. If the R^2 value is closer to 1, it implies a good linear response of the detector with the delivered monitor units.

Generation of Gy/CU table for midpoint dose estimation

In order to determine the midpoint dose, the relationship between the midpoint ion chamber dose and CU of EPID was studied and a table was generated which is used to convert the CU of EPID into dose in gray, for different field sizes and phantom thickness.

Solid phantom, SP 34 phantom from IBA dosimetry was used in this study. The solid phantom material is RW3 which is white polystyrene similar to natural water and suitable for high energy photons and electrons measurements (User's Guide IBA). 20 solid phantom slabs of 1 cm thick, 30 x 30 cm^2 in dimension were placed on the couch and the source to surface distance (SSD) was set at 100 cm and the field size at 10 x 10 cm^2. The 0.6 cc chamber was placed at a depth of 10 cm from the surface. The EPID is placed at a distance of 150 cm, which gave sufficient clearance from the couch for the movement of the gantry to various angles. The ion chamber electrometer reading with the corresponding CU from portal dosimetry mode were noted. Different thicknesses of solid phantom ranging from 8.0 cm to 22 cm were used and the thickness was gradually increased in steps of 2.0 cm. In each measurement, the ion chamber was exactly kept at the midpoint of the total thickness and the SSD at 100 cm and the experimental set up is shown in **Figure 1**. The field sizes used were 5×5 cm^2, 8×8 cm^2, 10×10 cm^2, 12×12 cm^2, 15×15 cm^2, 18×18 cm^2.

The measurements were done for 100 MU, 15 MV photon beams and the corresponding dose and CU were noted. A Gy/CU look up table for the set field sizes and depths was generated for 15 MV photon beams and this table was used in the conversion of CU to absorbed dose in Gy in patient study and the reproducibility of the EPID is verified on daily basis.

The table was validated by measuring the dose using 0.6 cc ionization chamber and comparing it with the calculated dose, from the EPID CU and the Gy/CU values from the table, for rectangular field sizes and for different depths for a period of five months.

Figure 1. Experimental setup for Gy/CU table generation

Patient study

25 patients of cervical cancer treated with conventional Antero-posterior (AP) and Postero-anterior (PA) fields, 15 MV photon beams using SSD technique were selected for this study. Patients with thickness less than 20 cm were usually treated by conventional method at our centre. The thickness of the patients included in this study ranged from 15 cm to 20 cm and the equivalent field size from15 to 16.48 cm^2. A target dose of 2 Gy (1.0 Gy per field) was delivered daily to the patient using two field technique. Eclipse Treatment Planning System (Version 8.9) and pencil beam convolution (PBC) algorithm with no inhomogeneity correction was used for the calculation of monitor unit. Varian linac has different image sequence for acquiring EPID images. In this study EPID measurements were carried in the portal dosimetry mode on the first day of the treatment for both AP and PA portals and repeated after every 5# for 5 weeks. A total of 10 portal images were acquired for each patient and altogether 250 portal images were studied.

The CU value corresponding to the central pixel of the irradiated field was noted for each portal and converted into dose using dose conversion factor ($dcf_{CU\rightarrow Gy}$) obtained from the generated Gy/CU look up table using linear interpolation. The thickness of the patient was checked on the day of portal imaging and differences in depth was accounted for in the calculation by a depth correction factor (cf_{dep}), where:

$$cf_{dep} = \frac{(PDD)_{on\ the\ day\ of\ acquiring\ the\ portal\ image}}{(PDD)_{Prescribed\ depth}} \quad \text{Eq. 1}$$

The midpoint dose (D_{mid}), calculated in Gy is compared with the prescribed dose and the percentage deviation was derived.

$$D_{mid} = CU \times \left(dcf_{CU\rightarrow Gy}\right) \times cf_{dep} \quad \text{Eq. 2}$$

Results

A graph was plotted between the ratio of CU/ MU, which was normalized to 100 MU and the exposed Monitor units which is shown in **Figure 2**. The EPID shows under response for lower MU up to 20 MU and good linear response of CU with MU (R^2=1), above 20 MU. The normally encountered MU value for pelvis cases in this study was in the range 100-150 MU per field and it was found that the EPID response was linear from minimum set MU of 20 to maximum 500 MU. Our results gave a decrease in linearity with a maximum of 5% in the range 5 to 20 MU, maximum of 2% for 20-50 MU and less than 0.5% for MU greater than 50 and up to 500 MU. This characteristic feature of EPID allows us to use it as a dosimetric tool in this study.

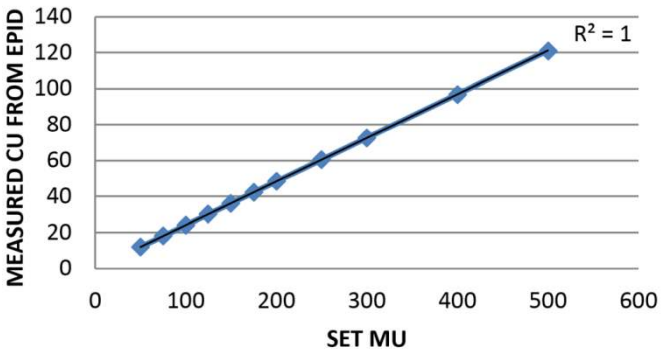

Figure 2. Linearity of EPID response (CU) with MU

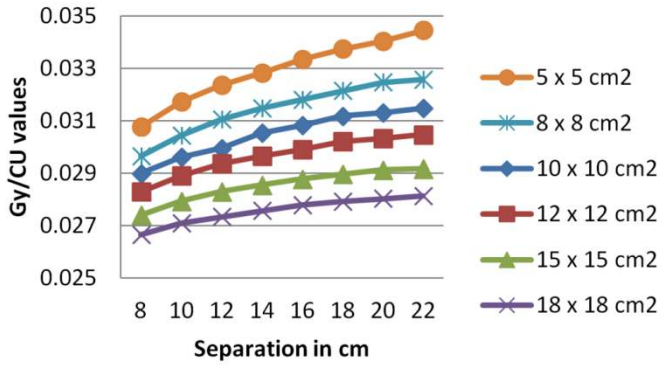

Figure 3. Variation of Gy/CU values with field size

The Gy/CU look up table, which contains the dose conversion factors for 15 MV photon beams generated from the phantom study, is shown in **Table 1**. The Gy/CU table shows that the dose conversion factor is dependent on field size and depth. It is found to decrease with increase in field size for a constant depth and increases with depth for a constant field size. Hence it becomes necessary to generate a table for the commonly used thickness and field sizes. The variation of the Gy/CU values for different field sizes is shown graphically in **Figure 3**.

The results of validation of the table for various rectangular field sizes and for a thickness of 15 cm, which were not used in the generation of Gy/CU look up table, is shown in **Tables 2** and **3** respectively. The results of the validation **Tables 2** and **3** show that the Gy/CU table, which has been generated with square fields and for thickness from 8 to 22 cm in steps of 2 cm, can be effectively used for any rectangular field size as the % deviation of the calculated and measured dose ranges from 0.00 to 0.40 % for equivalent field sizes from 6.86 cm^2 to 16.94 cm^2. The validation for a depth of 15 cm gave results with % deviation from 0.12 to 0.24%. The reproducibility of the validity of the Gy/CU look up table was also done.

Table 1. Generated look up Gy/CU table for 15 MV photon beams

Thickness (cm)	Field size in cm x cm					
	5 x 5	8x8	10 x 10	12 x 12	15 x 15	18 x 18
8.0	0.0308	0.0297	0.0290	0.0283	0.0274	0.0266
10.0	0.0317	0.0304	0.0296	0.0289	0.0279	0.0271
12.0	0.0324	0.0310	0.0300	0.0294	0.0283	0.0273
14.0	0.0328	0.0315	0.0305	0.0297	0.0286	0.0276
16.0	0.0333	0.0318	0.0308	0.0299	0.0288	0.0278
18.0	0.0337	0.0321	0.0312	0.0302	0.0290	0.0279
20.0	0.0340	0.0325	0.0313	0.0303	0.0291	0.0280
22.0	0.0344	0.0326	0.0315	0.0305	0.0292	0.0281

Table 2. Validation of Gy/CU table for rectangular field sizes

Field size (cm^2)	EPID CU	Gy/CU factor	Calculated dose (Gy)	Measured Dose (Gy)	% deviation
6 x 8	22.028	0.0331	0.729	0.729	0.00
7 x 10	23.051	0.0324	0.746	0.743	0.40
9 x 12	24.377	0.0312	0.760	0.760	0.00
8 x 15	24.626	0.0311	0.765	0.762	0.39
15 x 17	27.418	0.0288	0.789	0.787	0.25
16 x 18	27.887	0.0284	0.792	0.792	0.00

Table 3. Validation of Gy/CU table for a thickness of 15.0 cm

Field size (cm^2)	EPID CU	Gy/CU factor	Calculated dose (Gy)	Measured Dose (Gy)	% deviation
5 x 5	23.797	0.0331	0.788	0.789	0.13
8 x 8	26.095	0.0317	0.827	0.825	0.24
10 x 10	27.418	0.0307	0.842	0.840	0.24
12 x 12	28.634	0.0298	0.853	0.852	0.12
15 x 15	30.181	0.0287	0.866	0.865	0.12
18 x 18	31.569	0.0277	0.874	0.872	0.22

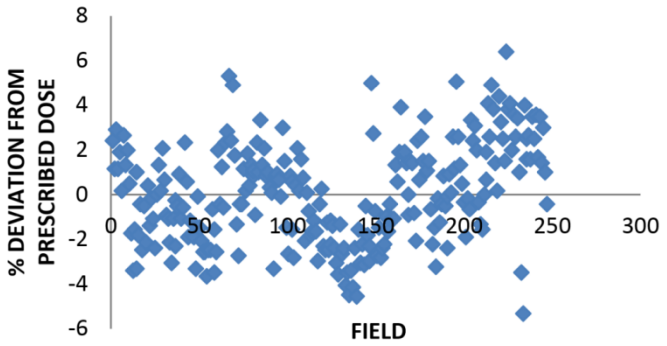

Figure 4. Scatter plot of % deviation of individual fields

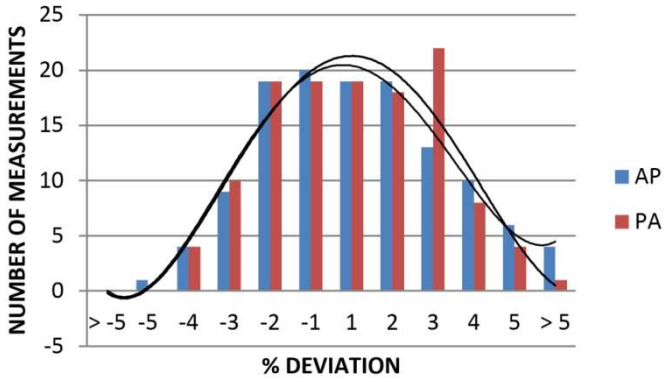

Figure 5. Histogram of results of % deviation of dose from prescribed dose

The average midpoint dose of 5 measurements calculated for 25 patients from the measured CU values along with standard deviation based on different patient thickness is shown in **Table 4**. The values of standard deviation in the above table indicate that there was minimum difference in the delivered dose to the patients measured for 5# at weekly interval. The deviation in the calculated dose to midpoint from the prescribed dose of 1.0 Gy, ranges from -2.6% to 3.7% for AP field and -3.1% to 2.2% for PA field. This implies that 100% of the measured dose was within ±5% and 92% was within the recommended acceptable level of radiotherapy dose delivery of ±3%, which is for the average midpoint dose of 5 fractions. This result is comparable to the in-vivo dosimetry of pelvis cases using TLD in literature [6,7]. Further the % deviation from the prescribed dose is independent of the patient thickness which justifies the fact that the table can be used effectively for any patient thickness.

The % deviation of the measured fields (250 in number), 10 for each patient was analysed and the scatter plot for the individual fields are shown in **Figure 4**. The scatter plot shows the individual percentage deviations of EPID measured doses for each fields and found that most of the measured doses are within the acceptable range when compared to the prescribed dose.

The histogram (**Figure 5**) shows the number of measurements within a different range of percentage deviation from the prescribed dose for the AP & PA fields. The histogram of AP and PA fields follows the Gaussian distribution which validates the statistical analysis of the measured patient doses. It is found that maximum number of measurements are within the ±3% range, that is 100/125 measurements of AP and 108/125 measurements of PA are within the ±3% range, 21/125 measurements of AP and 16 /125 measurements of PA are between ±3% to ±5% range and 5/250 measurements are above ±5% . This implies that 98% of the measurements are within ±5% and 83.2% are within ±3% for individual measurements with a standard deviation of 1.66% for AP field and 1.57% for PA field.

Table 4. Average midpoint dose along with standard deviation for 25 Carcinoma Cervix patients

S.No.	Patient thickness at field centre (cm)	Average measured dose for 5# at weekly interval in Gy at midpoint with SD	
		AP	PA
1.	15.0	0.974 ± 0.008	0.964 ± 0.007
2.		0.982 ± 0.008	0.969 ± 0.007
3.		0.998 ± 0.028	0.987 ± 0.023
4.		0.994 ± 0.011	0.974 ± 0.007
5.		1.014 ± 0.017	1.005 ± 0.018
6.	16.0	0.993 ± 0.012	0.984 ± 0.011
7.		0.981 ± 0.008	0.968 ± 0.005
8.		1.031 ± 0.018	1.012 ± 0.016
9.		1.019 ± 0.012	1.001 ± 0.014
10.		1.017 ± 0.031	1.005 ± 0.033
11.		1.030 ± 0.008	1.013 ± 0.011
12.		1.037 ± 0.022	1.022 ± 0.016
13.	17.0	0.993 ± 0.013	0.983 ± 0.009
14.		1.013 ± 0.020	0.996 ± 0.017
15.		1.021 ± 0.023	1.008 ± 0.024
16.	18.0	0.999 ± 0.014	0.984 ± 0.014
17.		1.006 ± 0.012	0.995 ± 0.014
18.		1.022 ± 0.010	1.008 ± 0.013
19.		1.011 ± 0.015	1.001 ± 0.016
20.		1.019 ± 0.021	1.002 ± 0.019
21.	19.0	0.992 ± 0.007	0.976 ± 0.001
22.		1.011 ± 0.011	0.999 ± 0.019
23.	20.0	1.024 ± 0.004	1.009 ± 0.005
24.		0.997 ± 0.012	0.983 ± 0.014
25.		1.002 ± 0.017	0.996 ± 0.011

Discussion

The purpose of this study was to investigate the percentage difference between the prescribed dose and the delivered dose to cervical cancer patients by using a simple methodology for dose estimation using EPID. Any detector to behave as a dosimeter should exhibit linearity with dose [8]. Several authors have studied the linear response of EPID with monitor units and reported about its under response for low monitor units [9-11]. Our results are comparable with values reported by Camilleri *et al.* [12] of 0.6% for MU range of 2-200 MU for 6 MV beams.

The accuracy and reproducibility of our methodology for the estimation of midpoint dose were validated for rectangular field sizes and different depth. The results of the reproducibility of the validation procedure over a period of 5 months was verified. This yielded a result with maximum deviation of 0.66% with SD ±0.214 for rectangular field sizes and a deviation of 0.71% with SD ±0.208 for different depth, for the estimated midpoint dose. This gave us the confidence that the table can be used for any patient thickness within the measured range of 8 to 22 cm and for any type of field size from 5 x 5 to 18 x 18 cm^2.

In order to estimate the influence of air cavity in the chamber sleeve on the effect of measured dose, the measurements were carried out with solid slabs without chamber insert. The results were found to be less than 0.5% variation with and without chamber sleeve. This systematic error of less than 0.5% was not included in this present study.

The sole purpose of in-vivo dosimetry is the estimation of point dose or planar dose to confirm the accurate treatment dose delivery to the patient. Several authors [13] have reported methods like arithmetic mean, geometric mean, a method developed by Rizzotti *et al*. using entrance and exit dose for midpoint dose estimation. The development in the portal dosimetry technology with EPID, has evoked interest in the estimation of midpoint/ mid plane dose from the EPID exit portal images by using back projection techniques. The back projection technique has been applied for only advanced techniques like 3D-CRT, IMRT and rarely applied for conventional treatments like simple AP-PA fields. As per the ESTRO report, booklet 1 [3], it is sufficient to measure a point dose at the entrance or exit, to estimate the dose at the midpoint, for in-vivo dosimetry. Moreover for an open parallel opposed field, estimation of midpoint dose is adequate for the verification of dose delivery. Our methodology is very simple and easy to adopt for any radiotherapy department for verification of the treatment dose delivery. By generating a look up table for the EPID available in the department, it is possible to estimate the midpoint dose received by the patients. The results of this method in the patient study involving 25 cervical cancer patients is comparable with the results obtained with other in-vivo dosimeters. The standard deviation of ±2.9% along with mean dose reported by Mortan JP *et al.* [14] using MOSFET for pelvis patients, SD of ±1.4% reported by Andrej Strojnik [15] using diodes and SD of ±2.6% by Alessandro M.Costa using TLD [16] are comparable with the SD values obtained in this study. Gandhi MA *et al.* [17] using diodes in rectal cancer have shown that 86.493% of measurements are within ±3%, are comparable with our results of 83.2% for individual measurements and 92% for the average dose for 5 fractions. It is clear from the above results that EPID in Linear accelerator is a substitute for any other in-vivo dosimeters like TLD, Diode and MOSFET.

Conclusion

The outcome of this study proves the efficacy of our methodology of using the Gy/CU look up table along with the EPID transit measurements for the estimation of midpoint dose. The study reveals that this method can be effectively used for verification of prescribed dose delivery for cervical cancer patients with minimal effort ,time and without causing any inconvenience to them unlike other in-vivo dosimeters like diodes, TLD and MOSFET and is suitable for a busy radiotherapy department. The study can be further used to investigate the uniformity of the dose delivery for other sites like Head & Neck, Thorax and for 3DCRT treatments. EPID response should be verified for a reference field on daily basis as a part of daily QA of the linear accelerator to assess its performance.

References

[1] IAEA (International Atomic Energy Agency). Absorbed dose determination in external beam radiotherapy: an international code of practice for dosimetry based on standards of absorbed dose to water. Technical Report Series no.398. IAEA, Vienna. 2000.

[2] Vasile G, Vasile M, Duliu OG. In-vivo dosimetry measurements for breast radiation treatments. Romanian Rep Phys. 2012;64(3):728-736.

[3] Van Dam J, Marinello G. Methods for in-vivo dosimetry in external radiotherapy. ESTRO booklet No.1. 2006.

[4] van Elmpt W, McDermott L, Nijstenn S, *et al*. A literature review of electronic portal imaging for radiation dosimetry. Radiother Oncol. 2008;88(3):289-309.

[5] Shrivastava SK, Mahantshetty U, Narayan K. Principles of radiation therapy in low-resource and well-developed settings, with particular reference to cervical cancer. Int J Gynaecol Obstet. 2015;131(S2):153-158.

[6] Leal MA, Viegas C, Viamonte A, *et.al*. Thermoluminescent chip detector for in-vivo dosimetry in pelvis and head and neck cancer treatment. Appl Radiat Isot. 2010;68(4-5):795-798.

[7] Evwierhurhoma OB, Ibitoye ZA, Ojieh CA, *et al*. Verification of entrance dose measurements with thermoluminescent dosimeters in conventional radiotherapy procedures delivered with Co-60 teletherapy machine. Ann Med Health Sci Res. 2015;5(6):409-412.

[8] Seco J, Clasie B, Partridge M. Review on the characteristics of radiation detectors for dosimetry and imaging. Phys Med Biol. 2014;59(20):R303-R347.

[9] Greer PB, Popescu C. Dosimetric properties of an amphorous silicon electronic portal imaging device for verification of dynamic intensity modulated radiation therapy. Med.Phys. 2003;30(7):1618-1627.

[10] McCurdy BM, Luchka K, Pistorius S. Dosimetric investigation and portal dose image prediction using an amorphous silicon electronic portal imaging device. Med.Phys. 2001;28(6):911-924.

[11] Winkler P, Hefner A, Georg D. Dose-response characteristics of an amorphous silicon EPID. Med Phys. 2005;32(10):3095-3105.

[12] Camilleri J, Mazurier J, Franck D, et.al. Clinical results of an EPID- based in- vivo dosimetry method for pelvic cancers treated by intenstity modulated radio therapy. Phys Med. 2014;30(6):690-695.

[13] Huyskens D, Van Dam J, Dutreix A. Mid plane dose determination using in-vivo dose measurements in combination with portal imaging. Phys Med Biol. 1994;39(7):1089-1102.

[14] Morton JP, Bhat M, Williams T, Kovendy A. Clinical results of entrance dose in-vivo dosimetry for high energy photons in external beam radiotherapy using MOSFETs. Austral Phys Eng Sci Med. 2007;30(4):252-259.

[15] Strojnik A. In-vivo dosimetry with diodes in rectal cancer patients. Radiol Onco. 2007;41(4):196-202.

[16] Costa AM, Barbi GL, Bertucci EV, *et al*. In-vivo dosimetry with thermoluminescent dosimeters in external photon beam radiotherapy. Appl Radiat Isot. 2010;68(4-5):760-762.

[17] Gandhi MA, Buzdar SA, Fatmi S. In-Vivo dosimetry with diode for the treatment of pelvic malignancies. Austin Oncol Case Rep. 2016;1(1):1004:1-4.