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Evaluation the Dose Verification Using Diode Versus TLD as *in-vivo* Dosimeters for External Radiotherapy

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BACKGROUND : Conformal radiotherapy was the first step toward patient-specific treatment, this is, in turn, arise the need to perform quality dose verification (DV) with in-vivo (IV) dosimetry. **Aim**: two common IV dosimeters were compared separately, diode and thermoluminescent dosimeters (TLD), the dose was compared with calculated dose and the isocenter dose measured with ion chamber (IC). **Materials and Methods** : First the absolute dose was measured with PTW Farmer IC (0.6 cc) on Varian machine model Unique) for twenty cancerpatients planned in 3D conformal radiotherapy, selected to cover different clinical sites, the dose was calculated in Eclipse treatment planning system (TPS). Then in the treatment position, pre-treatment DV dosimetry was performed using: Sun nuclear Semiconductor diode and TLD. **Results**: the dose measured with Diode had less variance (-1.94±2.05) with TPS than dose measured with TLD/TPS (4.08 ±6.51), when comparing the dose measures with IC this discrepancy is not the case with IC/TPS as they were measured in the isocentre point and compared with prescribed doses **Conclusion:** The Comparison between the two detectors revealed the limitation of both; discrepancies with Diode measurements approached less variance with accumulated dose give it the superiority for in-vivo dosimetry. But for prescribed dose and for absolute dose measurement IC was optimum to provide patient-specific measurement with MU double check. Calculating the difference with IV-dosimeter/IC could be used to measure absorbed dose when performing in-vivo dosimetry considering the deviation IV- dosimeter/IC correction factor.

Keywords: Dosimetry, dose verification, treatment planning system (TPS), Diode, TLD.

Introduction

Limiting the probability of local recurrence combined with the need to increase the certainty of dose delivery through in-vivo dosimetry. The need for in-vivo dosimetry combined with superficial dose to ensure suitable skin dose delivered to the case to lower the probability of local recurrence and skin recurrence[1]. Regarding dose verification in linear accelerator the ion chamber is the dosimeter that's mainly recommended for both machine calibration and patient-specific quality assurance QA as reported in multiple publications due to due to its precision, availability, and relative ease of use [2].

For in-vivo dosimetry Semiconductor diode and thermoluminescent dosimeters (TLD) are two common dosimeters beside IC. In 2005 AAPM released task group No. 62 for diode IV dosimetry for patients receiving external beam RT[3] were cross calibrated versus IC. Diodes also a popular IVD (internal verification device) due to Multi-center study in UK cancer centers aiming to determine IVD implementation in the UK in 2014 [4]. The semiconductor diode classified as real-time in-vivo dosimeter [5], for primary use relevant correction factors need to be inserted to increase its accuracy for in-vivo dosimetry either with 6MV [6] or higher photon energies in different sites [7], diodes also approved to be

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suitable for dose verification of electron compared to plane parallel ionization chamber [8], and cobalt .Technically diodes are characterized by dose rate dependent sensitivity [9] .For clinical application diodes were examined versus IC to provide real-time patient dose verification for breast carcinoma [6], head and neck cancers and pelvic cancers [10], pelvic malignancies [11], and for Total Body Irradiation TBI [8].

Thermoluminescence dosimeter (TLD) is characterized by its ability of measure superficial dose even with electron beam [12], and Cobalt 60 using SSD technique [13], either with external beam radiotherapy [14] , dose to anterior rectal wall in prostate cancer through proton therapy [15], high dose rate (HDR) brachytherapy to minimize positional uncertainty[16].

The current study aims to compare the dose calculated in TPS versus dose received in LINAC treatment machine with three common dosimetry devices: farmer IC as standard chamber for dosimetry in compared to the two vivo dosimetry systems, TLD and semiconductor diode to define sensitivity of each and suitability in pre-treatment dose verification for 20 patients randomly selected to cover different clinical sites.

Material and Method

Patient Demographics

Cases were calculated in Eclipse treatment planning system, to receive treatment in Varian treatment machine model Unique, a single energy machine provides 6MV photon beam with 1cm multi-leaf collimators. Patients included in this study were randomly selected to cover different clinical sites treated in 3D conformal radiotherapy techniques (forward intensity modulated radiotherapy IMRT), which enable us to examine the effect of physical parameters, including: separation, surface curvature and medium heterogeneity either with bone or lung tissue. Selected cases tabulated in Table 1 below with the percentage of each site and number of patients included.

The dosimetry system used

I- The absolute dose measurement was performed in PTW Farmer ion chamber (0.6 cc) model 30010.

TABLE 1. Distribution of clinical sites included in quality assurance .

Diagnosis	Number of patients	%
Glioblastoma	2	10%
Breast	5	25%
Lung	1	5%
Esophagus	1	5%
Head and Neck	1	5%
Rectum	5	25%
Endometrium	3	15%
Bladder	1	5%
Sarcoma	1	5%

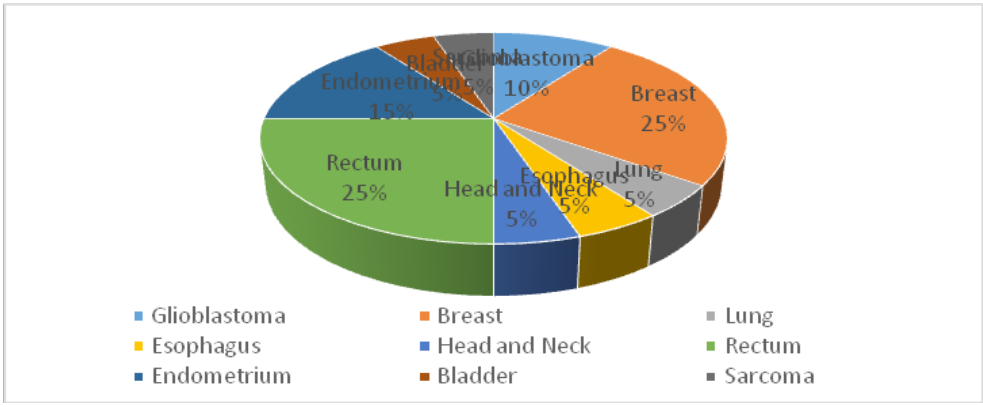

Fig.1. Distribution of cancer sites included in current dosimetry study.

II- IBA Sun nuclear Semiconductor diode had been calibrated (cross calibrated with ion chamber) for entrance/exit absorbed dose verification at reference conditions to consider required correction factors (SSD, field size, gantry angle, and wedge) which enable the diode to be used as for pre-treatment dose verification in the isocenter point.

III-The Thermo-Luminescent Dosimeter (TLD) disk shape with 4 mm diameter and 0.1 cm thickness. TLD packets had been Calibrated by irradiated to given doses (150 cGy, 200 cGy, 250 cGy) delivered from LINAC at 100cm SSD, 1.5 cm depth in solid phantom, 10 cm backscatter of solid phantom, and field size (10 x10) cm^2. to provide a dose rate of 1 cGy/MU according to the machine calibration setup. The packets were approximately 1 x 1 x 0.2 cm^3 and contained 45 mg of powder in each. All TLD packets were kept together until the time of delivery, and again until time of readout so that any background radiation collected by the TLD would be the same for each packet and so all the TLD maintained the same thermal history. They were distributed around the center. Count per irradiated dose displayed in calibration curve shown in Fig. 2.

Practical steps for IV- dosimetry

I- Dose measurement for ion chamber performed at 100cm SSD the IC inserted to water-equivalent solid sheets, solid phantom formed of solid slabs that comprise a cubic phantom of 30x30x30 cm^3 dimensions.at 10 cm depth Fig. (3-A and B). [16].

(Isocentre dose with gantry rotation)

- The ion chamber, considered as the reference of measurement, and hence was compared to the dose measured in-vivo with each dosimeter.

II- To perform in-vivo dose verification for clinical cases we placed 15 sheets of water-equivalent sheets then placed 1cm Bolus above the diode covering the entire surface field size, adjust corresponding SSD then measured the dose for each field based on planning system at fixed gantry plan verification created on Eclipse planning system at 100cm SSD (Figure 3:-C-and -D-). The bolus was added hence using p-type semiconductor diodes recommended to be done with buildup caps for clinical use [7].

III- The same steps of were repeated with TLD except that we used 5 chips of TLD distributed around the center of irradiation field with calculation of MU then measured at heated oven, to calculation corresponding dose based on heat generated due to irradiation at 100 cm SSD [18].

Calculation of variance

The discrepancy δ between the measured dose of each dosimeter and TPS calculated dose was calculated for each patient, using equation:

$$\delta\,(\%) = ((\text{Dose}_{\text{Dosimeter}} - \text{Dose}_{\text{TPS}})/\text{Dose}_{\text{TPS}}) * 100$$

The same equation also used to calculate the difference of each dosimeter with the dose measured in the ion chamber as performed previously [7].

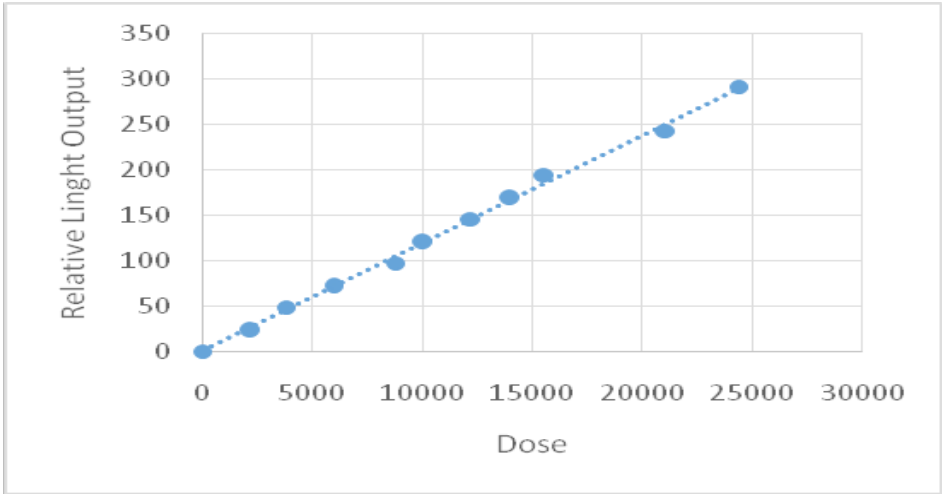

Fig. 2. TLD calibration curve with linear response to radiation.

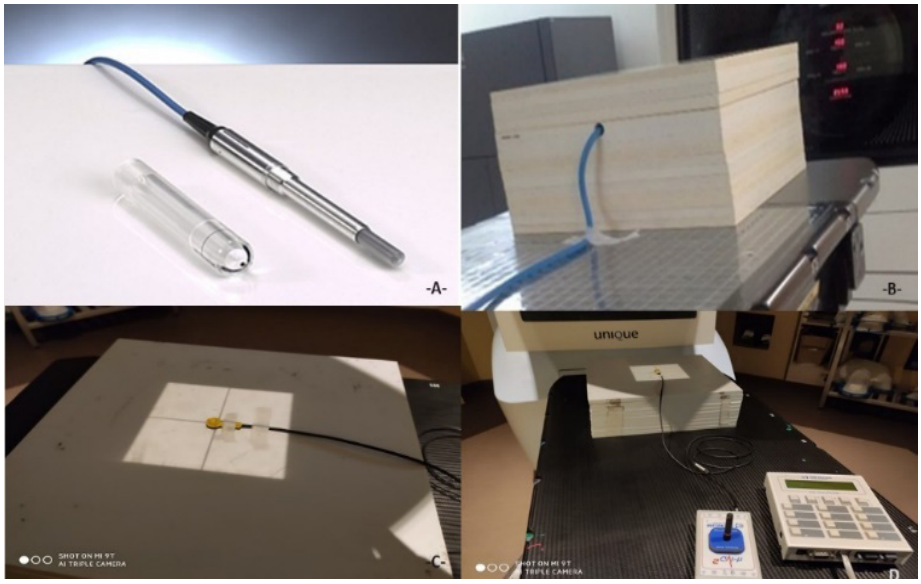

Fig. 3. PTW farmer 0.6 ion chamber (A), the IC placed at 10cm depth for absolute dose measurement (B). Diode positioning centralized in the isocentre point of light field (C) and connected to signal receptor and adaptor (D).

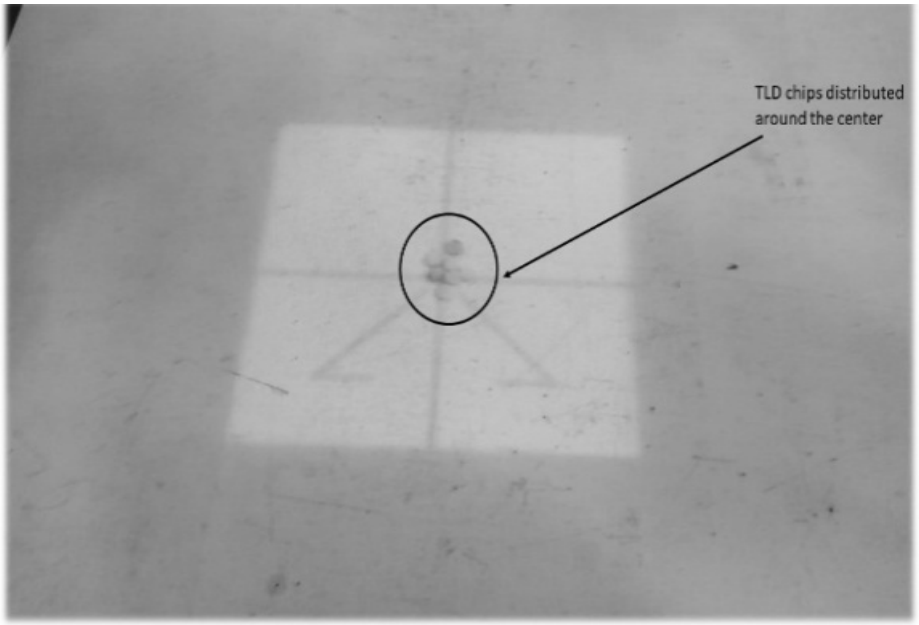

Fig. 4. TLD packets distributed around the center.

Results and Discussion

Absolute doses measured with farmer ion chamber versus TPS

Statistical analysis illustrated in Table 2. For point dose measurement for each plan

TPS calculated dose versus measured dose with PTW Farmer chamber as illustrated in the Fig.5.

Each in-vivo dosimeter was compared separately versus dose calculated by the treatment planning system (TPS), and then compared to dose measured with IC.

For in-vivo dosimetry the variance of each dosimeter /TPS was calculated from equation (1), the statistical difference illustrated in Table 3.

TABLE 2. Descriptive statistics for ion chamber measurements compared to TPS calculations.

	No. of patient	Range	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
TPS	20	117.0	153.0	270.0	189.550	6.3235	28.2796
IC	20	120.0	150.0	270.0	189.200	6.3956	28.6018
Valid N (listwise)	20						

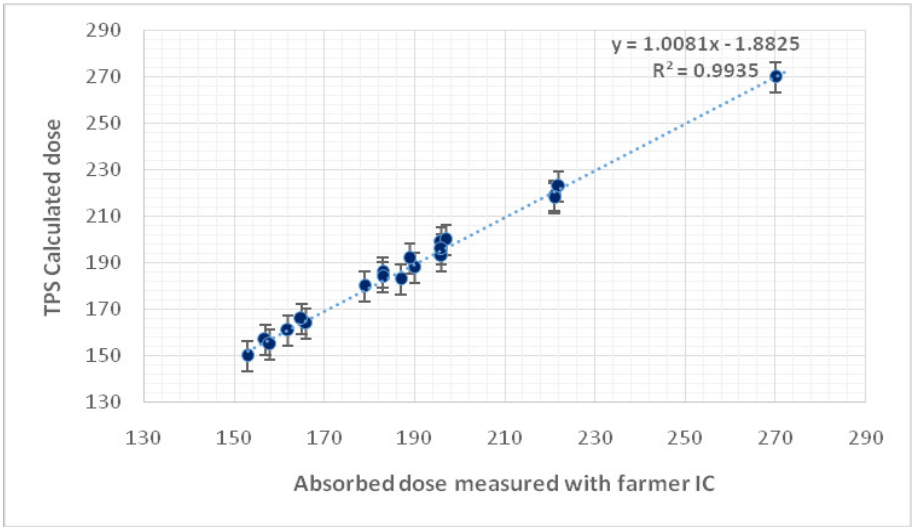

Fig. 5. Regression line with estimated errors between doses measured by Ion Chamber and prescribed dosec Gy unit.

TABLE 3. Descriptive statistics comparing TLD and Diode readings.

	TPS	DIODE	TLD
Mean	111.57	109.465	115.79
Standard deviation	13.0416	13.54	12.95
Standard Error	2.91	3.03	2.897
R^2	-	0.97	0.72
Minimum	87.5	83.5	95
Maximum	139	134.2	151.3
Difference from TPS	-	-1.94±2.05	4.08 ±6.51

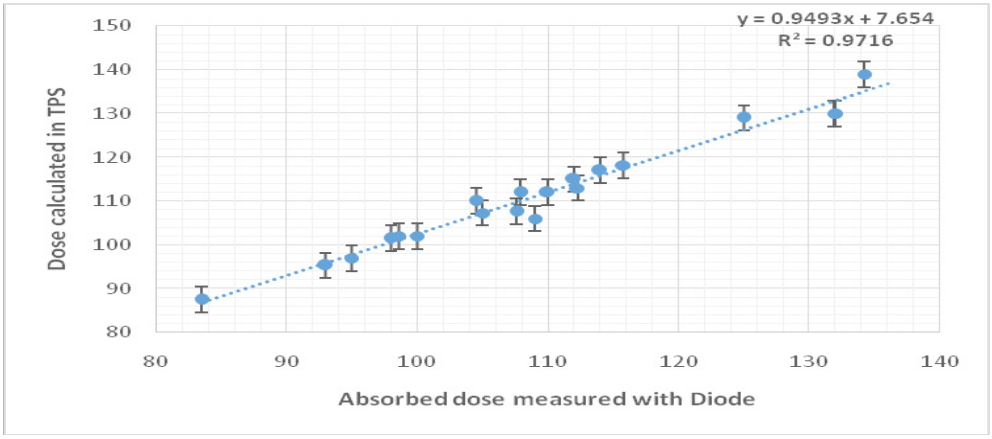

Fig. 6. Regression line with estimated errors between dose measured by Diode and TPS calculated dose.

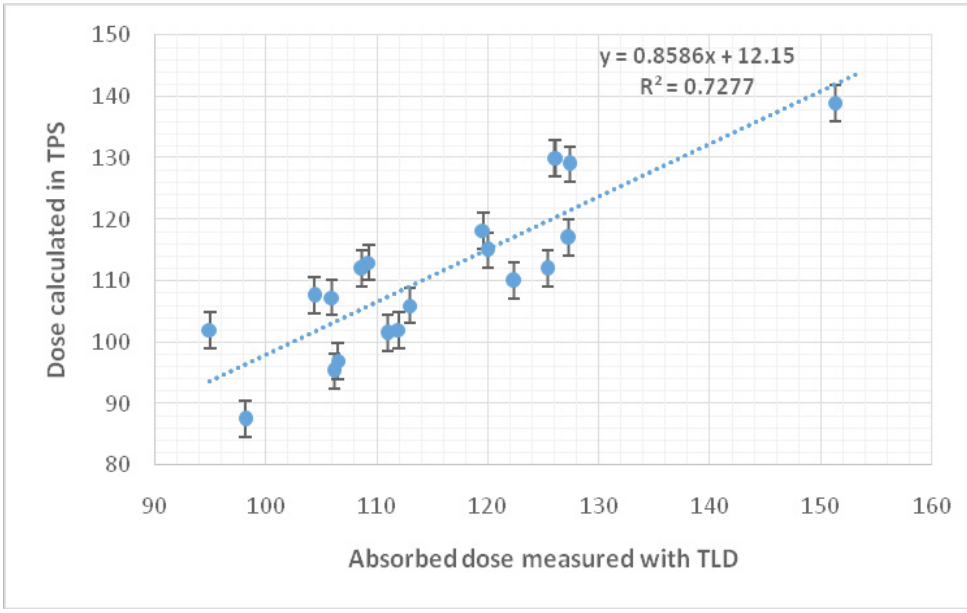

Fig. 7. Regression line with estimated errors between dose measured by TLD and TPS calculated dose.

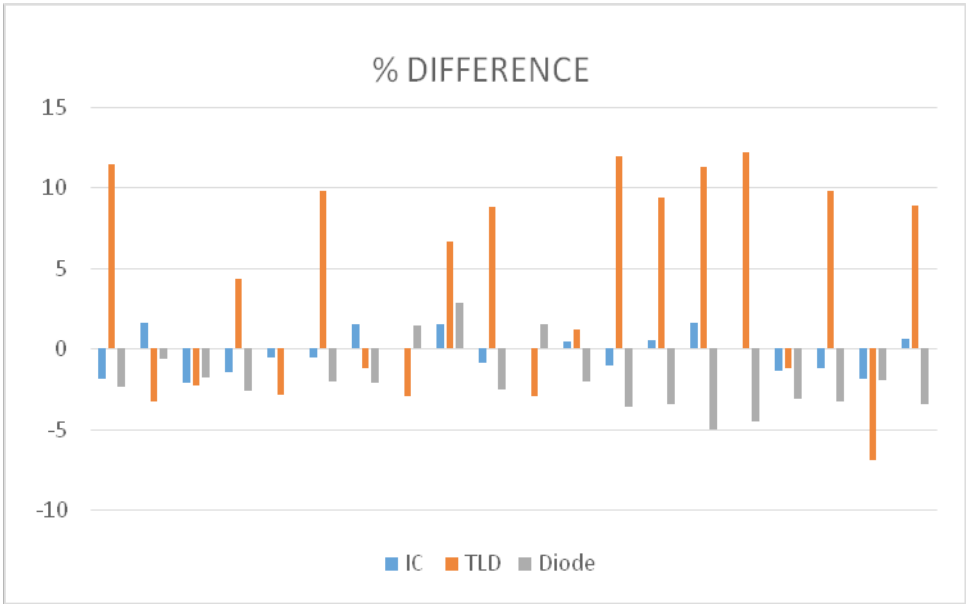

Fig. 8 . Percentage variation with dose measured in each dosimeter versus TPS calculated dose.

Discussion

Absorbed does measured with IC were characterized by small deviation (((28.6-28.2)/28.2) x 100) = (1.4%), with the ratio 117 / 120 revealed conformity within 97.5% differences with IC, the difference with linear response appears as well in data distribution where The whole measured points fit the linear with calculation dose which this is mainly due to commissioning data on planning system was measured with IC, as recommended on technical report series 398 released from IAEA[17].

With the In-vivo dosimetry the variance found between Diode/TPS (mean± SD) (-1.94±2.05) was lower than the mean variance calculated between TLD/TPS (4.08 ±6.51). This represent the lower deviation expected between TPS and Diode measurement, which emphasized with distribution of data illustrated in Fig. 6 and Fig. 7 where the Distribution within different conditions indicates certain cases of law variance and other with higher difference. The above measurements with semiconductor diode in figure 6 illustrate good agreement with the calculated dose could

be explained because of relative higher depth with angular effect (transition of calculation from angular to fixed-gantry plan verification) meets another conclusion made for endometrial dose verification hence diode approved to have an angular sensitivity limitation [7].

for patient IV dosimetry lower deviation appears in diode as describe in paper published by Gandhi et al 2016 [11], who examined pelvic metastasis with diode, where deviation up to 85% also the outcome of head and neck cancers which approved to be within 8% between the TLD and reconstructed doses may be a result of the several problems including the inherent relatively large uncertainty of TLD. Such result meets to a large measurement of previous studies (8-11). In semiconductor diode the variation was lower with higher regression, which makes it recommended for total body irradiation and Pelvic malignancy. [8,11]. The highest difference of TLD might be explained because of transitions of TLD from our center to another center for dose scanning while diode enable direct instant dose measurements and IC represent the tool of primary dose assessment which in turn had the least variance when re-measured for dose verification. However, both diode and TLD approved to provide suitable wireless for in-vitro dos e verification. Such findings might help to provide guidelines for the local clinical implementation of these practices (dosimetric verifications) as it examined different clinical sites with two accepted devices for dose verification.

Conclusion

Patient specific DV performed with IC isan important type of radiation dosimeter as the principal device used for calibration of radiotherapy beams as a double check with prescribed dose. For IV dosimetry diode was closer to calculated dose, however, both diode and TLD characterized by uniform difference versus calculated dose within different clinical sites which keep each of them an accepted device especially when seeking their additive values either of small field dosimetry with TLD or skin dose measurement with diode. Those outcomes highlight the limitation of each device for pre-treatment dosimetry.

Recommendation:

We recommend use tow system in verification for good quality and assurance form dose measurement in-vivo central point dose measurement with 2D dosimetry tool such as films or 2D array to examine dose distribution and beam fluence within the irradiated area especially with more advanced techniques in radiotherapy.

Study limitations : due to the work load of our treatment center, the number of included patients were limited. Beside the need for complete distribution assessment either in 2D or 3D QA dosimeters, for upcoming studies, and perform measurements in real cases.

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تقييم القياس العياري للجرعة باستخدام جهاز الدايود (ازدواجي القطب) مقابل جهاز مقياس الوميض الحراري في القياس السطحي لحالات العلاج الإشعاعي.

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يعتمد العلاج يعمل الإشعاعي ثلاثي الأبعاد على محاكاة شكل الورم لمحاولة تقديم علاج على قدر من التخصص يجعله مميزا لكل حالة دون غيرها, وهذا بالتبعية يزيد من اهمية معايرة هذه الحالة للتأكد من صحة الجرعة التي يفترض ان تصل اليها.

استخدام نوعين من اجهزة القياس الاشعاعي الشائع استخدم كل منهم لقياس الجرعة:جهاز الدايود (ازدواجي القطب) و جهاز مقياس الوميض الحراري. (ومقارنة هذه الجرعة اولا بالجرعة الموصوفة وثانيا بالجرعة المقاسة باستخدام غرفة التأين الإشعاعي.

اولا: قياس الجرعة الممتصة باستخدام غرفة التأين من النوع فارمر لقياس الإشعاع الصادر من جهاز المعجل الخطي موديل فاريان لعدد عشرين حالة تم حسابهم على جهاز التخطيط الإشعاعي (اكليبس) لتلقي علاج ثلاثي الأبعاد. وتنوعت الحالات لتشمل أعضاء الجسم المختلفة. وبعد ذلك- قبل بداية العلاج تم حساب الجرعة الممتصة لكل حالة باستخدام كلمن الجهازين موضع المقارنة.

الجرعة المقاسة باستخدام جهاز الدايود أظهرت في المتوسط
(فارق اقل مع جهاز التخطيط الإشعاعي (2.0±1.94

(مقارنة بالجرعة المقاسة بمقياس الوميض الحراري (4.08 6.5±

وعند مقارنة لكلا الجهازين مع الجرعة المقاسة من غرفة التأين بالجرعة المحسوبة على جهاز التخطيط الإشعاعي لم يظهر هذا الفارق كونها تمت عند النقطة المركزية للعلاج قورنت بالجرعة الموصوفة .

عند مقارنة كلا الجهازين ظهرت حدود لاستخدام كل منهم, القياسات بجهاز دايود أظهرت فارقا أقل مما يجعله مناسبا للقياس السطحي على المريض, أما القياس للمقارنة بالجرعة الموصوفة وتستخدم غرفة التأين لهذا الغرض بجانب تقييم حسابات جهاز تخطيط لعدد وحدات العد (الزمن المكافيء) اللازمة لتوصيل الجرعة. ومقارنة قياسات كلا الجهازين وقياسات غرفة التأين ضروري للتمكن من قياس الجرعة علي المريض مع اعتبار حساب مكافي لنسبة الخطأ المحتملة من كل منهم قياسات الجهاز مقسومة على قياسات غرفة التأين