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Dose Evaluation in the Movement Couch of the Total Body Irradiation Technique Using Semiconducting Diodes and Thermo luminescence Detectors

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Abstract:
Aim: *The present study is devoted to evaluate the dose at different points defined on the patient using semiconducting diodes and thermoluminescence detectors to excute verification of the dose at these relevant points calculated by means of movement couch and Beam - Zones method of the Total Body Irradiation Technique.*
Material and Method: *In this technique; 11 patients using 6 - MV X-ray in the (non-standard) conditions lying on the couch (supine and prone positions) were treated. Barry translation couch positioned in the extended SSD on the floor of the treatment room of distance (200 cm) was used. The couch was moving (280 cm) with fixed machine dose rate (300 cGy/min), and constant velocity which is been calculated from the (beam-zone method) depending on the length, different separation in different organs, thorax wall separation, and the lung density of each patient individually.*
Results: *Comparison between calculated dose values at (orbit, lung under the shield, umbilicus, and knee) and the corresponding results measured by means of semiconductor detectors proves that there is a quite agreement with deviation in the range of (17.18 ± 3.28)%, (11.13 ± 3.72)%, (13.8 ± 3.14)%, and (6.65 ± 1.56)%, at four different sites orbit, lung under the shield, umbilicus, and knee respectively. Additionally, further comparison between the calculated dose values and the corresponding measured results performed using TLD dosimeters at the same four sites proves that the deviation falls in the range of (23.27 ± 11.77)% , (14.18 ± 10.28)% , (16.52± 7.42)% , and (17.27 ± 7.01)%, respectively.*
Conclusion: *our results suggests that the semiconductor diodes and thermoluminesence detectors could be used for TBI quality assurance monitoring, although semiconducting diodes should remains the standard when critical dose measurements are performed. The semiconducting diodes, TLD results, and beam zones method calculations agreed within acceptable margins.*
Keywords: *total body irradiation; in vivo dosimetry; semiconductor diodes; thermo luminescent dosimeters.*
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I. Introduction:

The main purpose of radiation is destroying the DNA of the malignant cells by achieving high irradiation dose to the tumors and minimizing the dose to all surrounding critical organs which eliminate the complication of the radiation as much as possible.

In vivo dosimetry has been used to monitor the dose delivered to the patient in radiation therapy as verification of external beam treatment fields. A variety of detectors, including silicon semiconductor diodes and thermo luminescent dosimeters (TLD) [2-8] are currently available for in vivo dosimetry [1]. Total body irradiation is the preparatory condition for bone marrow transplantation.

The purpose of total body irradiation is destroying the bone marrow allowing for repopulation of the donor bone marrow cells, immunosuppressant, which helps in preventing the failure of the graft, and to eliminate the cancer cell population within the patients. Treatment includes receiving the patient either chemotherapy only or chemotherapy mixed with radiotherapy (total body irradiation). The most known cases to be considered in this regard are Leukemia's in adults and pediatrics and solid tumors in pediatrics. Leukemia could be classified in four types; acute lymphoblastic leukemia (ALL), myelodysplastic syndrome (MD), acute myeloid leukemia (AML),and chronic myeloid leukemia (CML).Also, solid tumors in pediatrics could be classified in four types; Neuroblastomas, Ewing sarcomas, plasmocytomas, and multiple myelomas. In other clinical diagnosis two types are to be considered; morbus hodgkin`s disease (MHD), and non-Hodgkin's lymphomas (NHL) [10,11].

Within the medical specialty of radiation oncology, Total Body Irradiation (TBI) is considered to be a special procedure that deserve great interest. This is because it deviates from standard radiation treatment technique in a number of significant ways. The differences' are basically due to the fact that the treatment fields

for TBI exceed the size of the scattering volume (The Entire Body) in all directions, and that the irradiated volume is highly irregular in shape. This study will identify these differences and offer solutions needed to guarantee accurate delivery of the prescribed dose and to achieve as homogeneous dose distribution as possible given the available treatment equipment and possible room geometry limitations [3,10].

Doses of total body irradiation used in bone marrow transplantation typically ranged from 10 to >12 Gy. For reference, a dose of 4.5 Gy is fatal in 50% of exposed individuals without aggressive medical care. However, at these doses, total body irradiation destroys the patient's bone marrow (allowing donor marrow to engraft) and kills residual cancer cells [10]. Non-myeloablative bone marrow transplantation uses lower doses of total body irradiation, typically about 2 Gy, which do not destroy the host bone marrow but do suppress the host immune system sufficiently to promote donor engraftment. In modern practice, total body irradiation is typically fractionated. Total Body Irradiation is used as a preparatory regimen for bone marrow reconstitution of patients with refractory malignancies leukemia, non – hodgkin's lymphoma, and neuoblastoma. These regimens typically employ supralethal doses of both chemotherapy and radiation and can produce major toxicity. In order to avoid possible morbidity or even mortality, it is important to clearly understand the techniques available to achieve a homogenous dose distribution. Additionally, it is essential that prescribed dose calculation methods for TBI must be standardized reaching higher degree of reliability in the time of entire body irradiation .

This study aimed at Implementation of Movement Couch & Beam Zones technique of Total Body Irradiation (T.B.I). Estimation of the degree of agreement between the calculated and measured dose distribution using in vivo dosimetry are to be utilized. In other words, the main purpose of this study is to ensure the delivery of homogenous dose to total body of the patient within ±10 % [3,8] of the prescribed dose, and to reduce the dose to especial organs as lungs, using 6 - megavoltage photon beam [3,9].

II. Material and methods:

There are many different TBI techniques being practiced around the world. The choice of a technique in a particular hospital depends on many factors like available equipment, photon beam energy, maximum possible field size, patient dimension, and treatment distance. Specific treatment parameters to be determined include field size, collimator angle, treatment distance, dose per fraction, dose rate, total dose, number of fractions per day, interval between fractions, beam energy, geometry to achieve dose homogeneity, bolus or beam spoilers to increase skin dose, shielding, and dose compensation requirements (e.g., lungs) [3,5,8,9,10].

Total body irradiations patients are treated using 6 - MV X-ray generated by (Siemens Medical Solutions, Malvern, PA) ONCOR expression linear accelerator. Siemens CT scanner Somatom Sensation version syngo with flat tabletop designed specifically for radiation oncology purposes. Using CT we take scout of the patient and it has been strongly suggested to measure the absorbed dose at the surface of the patient at (12) different regions (orbit ,chin ,neck ,supra sternal nudge ,mid.lung ,xipphisternum ,umbilicus , symph pubis , mid .thigh ,knee , mid . tibia and ankle) at the entry and exit of the beam under TBI conditions [4] . The reference dose to the patient should be specified as the total dose to mid abdomen at the height of the umbilicus. In this technique we treat 11 patients in the (non-standard) conditions lying on the couch (supine and prone positions). A schematic drawing of the treatment setup is shown in **Fig.1.a.b**.

In the present work, Barry translation couch [1-3,10] positioned in the extended SSD on the floor of the treatment room of distance (200 cm) has been used. It is moving (280 cm) with fixed machine dose rate (300 cGy/min), and constant velocity which has been calculated from the (beam- zone method) published by Quast and Quast & Glaeser [4,5,10] depending on the length, different separation in different organs, thorax wall separation, and the lung density of each patient individually. The treatment fields for TBI exceed the size of the scattering volume (the entire body) in all directions, and the irradiated volume is highly irregular in shape. So, it needs a special considerations in the calculation process and dose verification, where the total Number of MUs required to deliver the per field prescription dose of 120 cGy was in the range of 1500–1700 MUs depending on the average thickness of the patient [4,8].

A range of TBI treatment techniques is utilized in the present work where (supine and prone position) [1,4,8,10] technique enable CT localization considering tissue in homogeneities and individual body contours in treatment position, have accurate beam zone calculations **Fig .1.a.b.** The present study will focus on one technique using translating bed carrying out the patient on the extended SSD, with open field 40 ×40 cm at isocenter and 80×80 cm in the extended SSD on the ground [1,10], with constant speed. To reduce the dose to the prescribed lung shielding of calculated thickness are needed.

We use lead rubber material of thickness (0.8) cm and the lead material of (0.2) cm has been used as lung shields which is attached directly to the skin of the patient on the level of the lungs to suppress the dose to lungs up to (25 – 30) % which is 9 Gy in 5 fractions on 5 days of total prescribed dose of the total body irradiation dose which is 12 Gy per five fractions 2.4 Gy per fraction for five days [9,10]. For total-body irradiation (TBI) using the translation method, dose distribution cannot be computed with computer-assisted three-dimensional planning systems. Therefore, dose distribution has to be primarily estimated based on CT

scans (beam-zone method) which is followed by in vivo measurements to ascertain a homogeneous dose delivery.

The lung shield which is positioned in (Anterior – Posterior) (A/P – P/A) [3-10] allows reducing the lung dose without under dosage of other target cells. The increase in dose due to the low lung density and due to scattering from surrounding tissues has to be into consideration. Thus, their shapes and thicknesses have to be measured or taken from CT – data by calculating the lung density, and the thorax wall separation in different points at least 10 points in each site.

In this study transmission shielding of the lungs is directly fixed to the skin, the patient can be positioned lying in the translation couch without any fixation. Shielding materials are made of lead rubber cut-outs, or layers of thin lead sheets (for high energy photons, the lead has to be covered by low density material) to reduce the patient toxicity due to the direct contact with skin of the patient.

The dose to the lungs was measured under the lead rubber shield which was used attached directly to the skin. So, there are no further calculations of diversion factor for the lung shield. We check the position of the shields for both lungs by another CT scan before the first session to ensure the positioning of the shields**.**

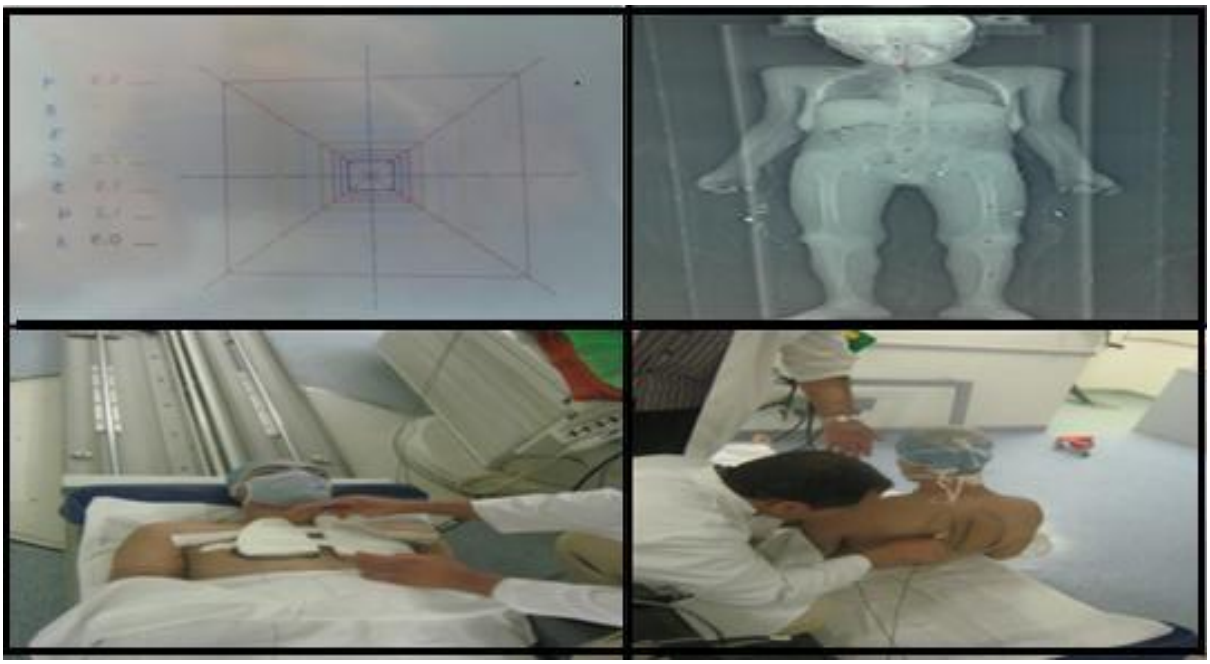

Figure .1.a.b:

- **View of (Beam – zone method).**
- **patient's setup for total body irradiation with a Barry translation couch [1,10].**
- **Semiconductor Diodes, Thermolumenscence detector's, and lung shields are fixed to their positions.**

1. Phantom Dosimetry

Humanoid phantom (Cecil PTW child phantom) [8] represent child of 10 years old it is tissue equivalent of electron density (1.045 g/cm3). It has been used to simulate the patient set-up. Identical method was used to construct tissue deficit compensator for the phantom. Surface and midline doses of orbit, lung under the shield, and umbilicus level were similarly measured. Contrary to patient setup, Humanoid phantom was lying in the total body irradiation couch in its both sides (Anterior – Posterior)

2. Semiconductor Diodes Dosimetry

The in vivo semi conductor probe response may vary with many different factors e.g. SSD, field size, incidence angle, dose per pulse, temperature, accumulated dose, and patient thickness. All these factors may change from detector to another .So, it is important to calibrate the detector in the same conditions of radiation before using it.

The technical aspects of the used semiconducting diode is PTW – Freiburg can be used in relative dose measurements at high energy photons of type T60010M with lead build – up material that of (2 g/cm^2), P – type Si with response range from 200 to 255 nC/Gy, directional dependence of ± 60 deg from perpendicular < 5% at 6 – MV which is used in our case [1], with electrometer UNIDOS (PTW, Freiburg, Germany).

3. TLD Dosimetry

Chip shaped TLD [3,6,7,8] - GR700A (Harshaw Chemie BV, the Netherlands) LiF (7- LiF: Mg, Cu,P) circular chips, dimensions: (4.5 mm diam. X 0.8 mm), linear response from (0.5 – 1) μGy up to 12 Gy with batch uniformity < 5% TLD oven (PTW-Freiberg, Germany) .The annealing step is to be done before every use at 240 ˚C for at least 10 minutes. TLD reading was carried out with PCL3 TLD system Fimel France reader at temperature range of 155˚C preheating then 260 ˚C final heating, the duration of each step is 6 seconds, TLDs were read 12 h after each irradiation of each patient. Senstivity test is done to the crystals after finishing of the treatment of each patient; we use the crystals which have ±5% sensitivity after excluding the patches which have sensitivity more than ±5%. The TLD crystals are exposed to known dose of (100 cGy) in the standard setup, SSD 100 cm, field size 10×10 cm^2, and at the isocenter [8] .

III. Results and Discussion:

The results of the present work show that there is a dose deviation in eleven patient of **(BMT)** in four different positions (orbit, lungs under the shield, umbilicus, and knee) using the semiconducting diodes against the thermolumencese detectors as shown in (**Table 3)**. Eleven patient irradiation doses were verified using semiconducting diodes and TLD as shown in (**Fig 2.a.b)**. The semiconducting diodes were measured at the midline of the patient in these four different positioned (Orbit, Lung under the shield, Umbilicus, and Knee) . TLD readings were measured at the surface in the exact four positions respectively. Corrected values were performed for TLD,s doses against semiconducting diodes doses as shown in **(Table 1).** Furthermore, the present work applied a second verification method that has been done to the surface dose using the Humanoid phantom **(Cecil)** as shown in (**Fig 3).** Entrance and exit dose values at the extended source to skin distance were the TLD readings are converted to midline doses using conversion factors for each site.

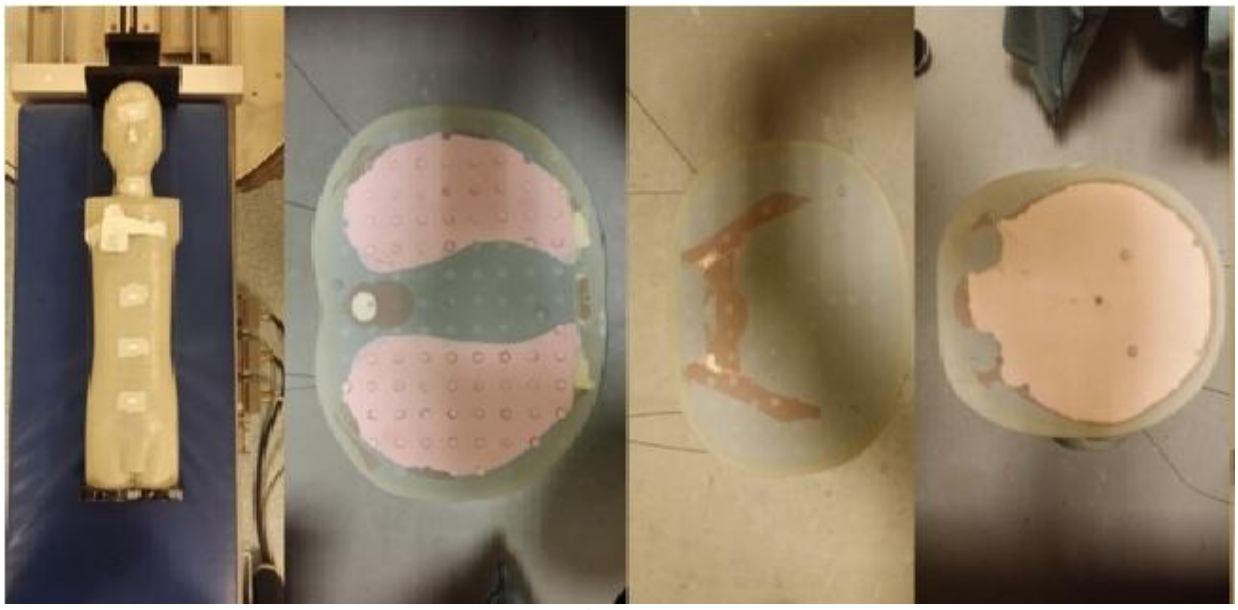

Fig 3.

- **The Humanoid phantom (Cecil). .**
- **Ceil with reading in (orbit, lung under shield, umbilicus).**

Starting with CT scan to the phantom. The planning has been calculated using the (Beam – Zone method) [4,5,10] and the doses to the orbit, lungs under the shield, and umbilicus was measured and verified using thermoluminescence detectors .The first set of TLD is located in a certain positions in the surface of the Humanoid phantom (Cecil) and second set of TLD dosimeters is located in the mid line of the phantom in the exact level of the surface TLD dosimeters .

The dose of the mid line is calculated and related to the surface dose and a conversion factor has been calculated to each site to calculate the equivalent mid line dose in our patients related to the skin dose which is been taken from the surface dose as shown in (**Table 1).**

Thermolumencence Detectors TLD,s on humanoid phantom Cecil							
Div . Factor from skin to mid line		orbit	neck	Lung under shield	Xipphis ternum	Umbilicus	Pelvis
		0.85	0.75	1.05	0.81	0.82	0.84
Mean Surface dose	count	8110.67	8828.67	8723.00	8153.00	8982.67	8440.67
dose in cGy	dose	52.62	57.37	56.67	52.90	58.39	54.80
Mean Midline dose	count	9468.00	11648.00	8285.00	10022.33	10949.67	10028.00
dose in cGy	dose	61.59	76.00	53.77	65.26	71.39	65.29
Dose in cGy after convertion	dose in mid line per field	91.93	113.44	80.26	97.40	106.55	97.45
Meas.per session	dose in mid line	183.86	226.87	160.52	194.80	213.09	194.91
ref. per session	calc.dose in mid line	237.00	244.00	180.00	237.00	240.00	238.00
Variation	var. between meas. And calc.	-22.42	-7.02	-10.82	-17.81	-11.21	-18.11

Table. 1

- **Comparison between the calculated and measured dose per session on the Humanoid phantom (Cecil) using the thermo luminescence dosimeters**.

Barry translation couch positioned in the extended SSD on the floor of the treatment room of distance (200 cm) has been used. It is moving (280 cm) with fixed machine dose rate (300 cGy/min), and constant velocity . the moving beam supposed to achieve more homogenous dose distribution in contrast standing beam particularly in body thickness separation **Table (2)** that irradiated with the same dose (240 cGy/fr).

Mean separation ± SD	
Orbit	18.86 ± 2.05
Mid lung	18.94 ± 2.48
Umbilicus	17.37 ± 3.56
Knee	11.9 ± 1.23

Table .2

- **Shows mean separation ± SD in four different positions (Orbit, Lung under the shield, Umbilicus, and Knee).**

The dose calculation for the different thickness and dimensions of body organs needs a lot of precautions to increase the probability of delivering dose uniformity in spite of the constant speed of the translation couch.

Our technique needs to establish dose verification policy to step at the pitfalls of inhomogenity doses in the transitional couch technique. semiconductors diodes and TLDs were used to verify the doses at different organs. Our results shows difference between measured and calculated dose as shown in **Table (3)**

TBI cases using semiconducting diodes for (11 patients)				
Site	Orbit	Lung under shield	Umbilicus cGy	knee cGy
Min	(213.9-247.7 cGy)13.66%	(160.2-173.1 cGy) 7.45%	(223.5-240 cGy) 6.88%	(223.4-234.8 cGy) 4.87%
Max	(202.5-257.6 cGy) 21.4%	(142.2-180.3 cGy) 21.11%	(196.7-240 cGy) 18.04%	(218-236.3 cGy) 7.73%
Mean	17.18%	11.13%	13.80%	6.65%
Median	17.81%	10.23%	14.61%	7.36%
SD	3.28%	3.72%	3.14%	1.56%
Results	(17.18 ± 3.28)%	(11.13 ± 3.72)%	(13.8 ± 3.14)%	(6.65 ± 1.56)%
TBI cases using Thermolumenscence detectors TLD for (11 patients)				
Site	Orbit	Lung under shield	Umbilicus cGy	knee cGy
Min	(233.5-231.2 cGy)1.01%	(175.4-178.3 cGy)1.63%	(232.5-240 cGy) 3.13%	(223.6-236.2 cGy) 5.34%
Max	(151.5-247.5 cGy)38.81%	(119-177.2 cGy) 32.86%	(176-240 cGy) 26.68%	(190.6-261.3 cGy) 27.06%
Mean	23.27%	14.18%	16.52%	17.27%
Median	20.43%	13.15%	17.81%	17.32%
SD	11.77%	10.28%	7.42%	7.01%
Results	(23.27 ± 11.77)%	(14.18 ± 10.28)%	(16.52± 7.42)%	(17.27 ± 7.01)%
P - value	0.34	0.53	0.20	0.24

Table .3

- **Comparison between semiconducting diodes and thermoluminescence detectors in dose variation at different four sites (orbit, lung under the shield, umbilicus, and knees).**

In the present work the differences between measured and the calculated doses were (-17.18 ± 3.28) % ,(-11.13 ± 3.72)%, (- 13.8 ± 3.14)%, and (- 6.65 ± 1.56)% by using semiconducting diodes for Orbit , Lung under shield , umbilicus and Knee respectively, and the differences between measured and the calculated doses were (- 23.27 ± 11.77)%, (- 14.18 ± 10.28)%, (- 16.52 ±7.42)%, and (- 17.27 ± 7.01)% by using TLDs for Orbit , Lung under shield , umbilicus and Knee , respectively . our results agreed with Chie E.K that stated that dose in homogeneity of over 20% could result from omitting regular quality assurance [11-12] . Ulla Ramm [1] et.al. stated that the deviation between measured and calculated doses were within ±5% might be results in using tissue compensator and variable transitional couch speed that illustrated that the discrepancy between our results and Ulla Ramm [1] varied between (6 - 12)%.

The TBI dose distribution is exhibits inhomogenity doses issue along the total patient's body so TBI dose verification needs further quality assurance and improvement of calculations and measured procedures . We recommended that using tissue compensator and variable couch speed to reduce the impact of different organ thicknesses.

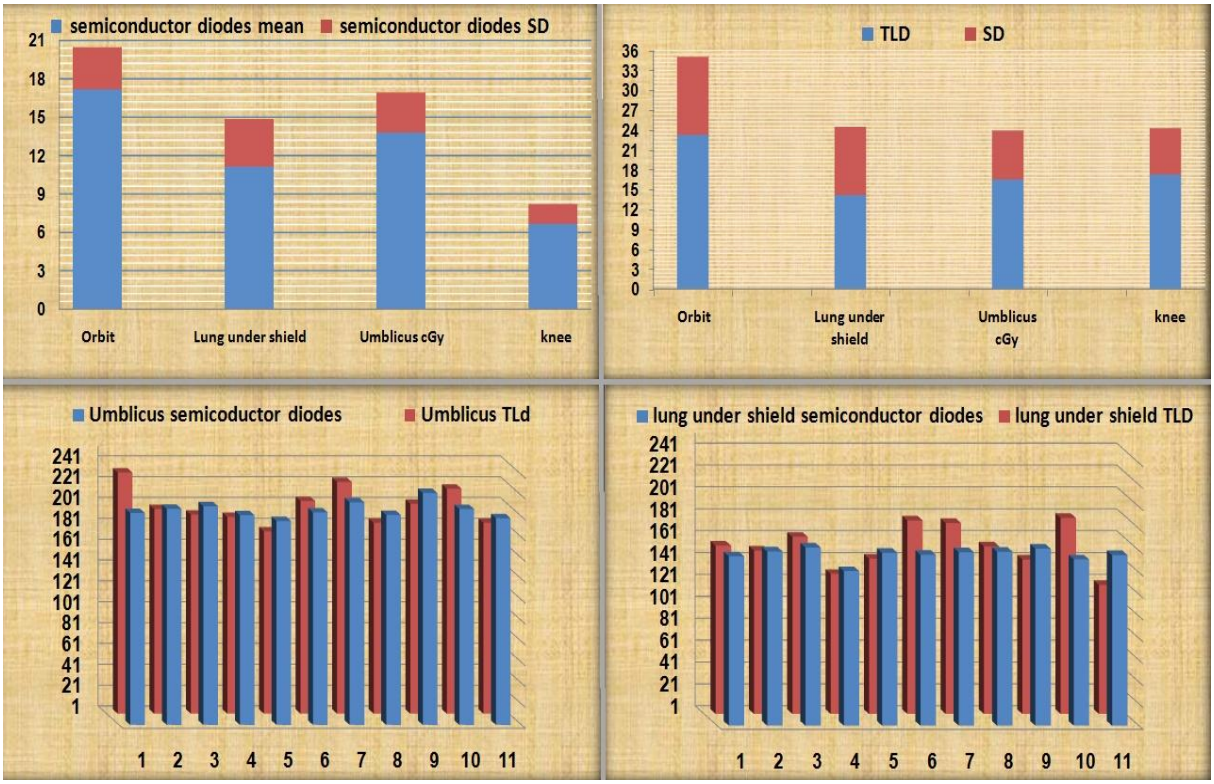

Fig 2.a.b.

a. Shows the mean ± SD in different four sites (orbit, lung under shield, umbilicus, and knee) using semiconductor diodes and thermolumenscence detectors.

b. Shows deviation in total prescribed and verified dose in different two sites umbilicus, lung under shield for 11 patient

IV. Conclusion:

In the present work semiconducting diodes and thermoluminescence detectors have utilized to validate the calculated values of the irradiation dose taken from the 6 MV x-ray generated by Siemens Oncor linear accelerator. The obtained results prove that TBI quality assurance monitoring is mandatory, semiconducting diodes should remain the standard when critical dose measurements are performed. The deviations in dose values given by different techniques are within the acceptable margins .Finally, more accurate and consistent results of dose homogeneity in dose delivery is possible by using the variable speed translation couch in addition of tissue compensators in extremities and neck sites, detectors which have less uncertainty in measuring the delivered dose is recommended.

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