Evaluation Physical Characteristics of Electron Beam at Extended Distances for Total Skin Electron Irradiation Technique

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Abstract: Background Electron beam radiotherapy, still the first option for the treatment of superficial tumors. Characteristics of electron beams from a Varian Medical linear accelerator are presented at extended SSD and the change of output with SSD was estimated. **Aim of the work:** was to present a full description of total skin electron irradiation technique applied with special Holder (tray for TSI), the dosimetry steps, Patient-specific in-vivo QA and monitor time calculations. **Materials and Methods:** The defining Z_{ref} for electron 6 MeV at extended distances to define the physical parameters required for the application of Total Skin Electron Irradiation (TSEI) technique including an effective SSD (SSD_{eff}) and the mean dose/MU at extended distance. **Results and Discussion**: There is no significate difference between PDD for standard energy and High dose rate (10Gy/min) and there no difference in value x- ray contination between two PPD curves one treated case was represented with before, during and after photo showing the positive response appears through the application of Stanford technique as a treatment course**.** **Conclusion**: The application of Total Skin Electron Irradiation Technique is applicable even without adding applicator to the gantry, however the complete dosimetry required for each treatment machine and mandatory for accurate application of the technique especially with narrow range of treatment.

[Aida Salama, Khaled M. El Shahat, Ehab M. Attalla, Ayat M. Saadeldin, Hussein M. Metwally. **Evaluation Physical Characteristics of Electron Beam at Extended Distances for Total Skin Electron Irradiation Technique.** *Cancer Biology* 2019;9(2):71-79]. ISSN: 2150-1041 (print); ISSN: 2150-105X (online). http://www.cancerbio.net. 11. doi:10.7537/marscbj090219.11.

Keywords: total skin irradiation – electron beam therapy – treatment planning system

1. Introduction

Generally, the disease known as Mycosis Fungoides (MF) is called also T-cell non-Hodgkin's lymphoma is a disease which rarely occur, and can be distinguished by the presence of epidermotropism, which is probably confused with the structures such as visceral organs and lymph nodes, at all stages MF is extremely sensitive to radiation specially in a condition where more than 50% of the body surface are affected. MF is subjected for treatment of definite areas by exposing the whole skin to an energy of 6 MeV (electrons). The regimen of treatment is composed of daily doses of 200 cGy for 10 days on each side of body and the total doses over 10days equaling 3000 to 3600 cGy [1]**.**

Another protocol for the treatment of cutaneous symptoms of progressed, therapy-refractory cutaneous lymphoma and leukemia is the Total Skin Electron Beam Therapy (TSEBT), where the available data revealed that it is an effective and well tolerated treatment choice in treatment. [2]. The complexity in the application of this technique relies on number of factors, basically technique and dosimetry for the application of this technique which had been described in details in task group number 51 released from the American association of physics in medicine in 1987 [3]**, *However a*** number of dosimetric studies had been presented for the application of Stanford technique for TSEI [4]**.**

First application of Stanford technique in Greece in which modality was developed on a linear accelerator with an immobilization structure designed to modulate the composite electron field and to sustenance the patient in the course of therapy. The patient must be in standing position during exposure to irradiation process in six situations totally. Special measurements were carried out for the validation of therapy suitability and the determination of physical sorts of the clinical electron field, via applying a parallel-plate ionization chamber and TLDs at water equivalent plastic and anthropomorphic phantoms. Measurements at the mentioned circumstances showed an uniform total points with intensity variation of ±4% at horizontal and ±2% in the longitudinal axises [5].

The number of modifications have been implemented to this technique, either with triple beams (instead of two) in 6 positions to solve the problem of small room dimension with unavailability of cone 25 [6].

This technique was in pediatric cases, with a revolving plate and harness, sere invented and additional to a standard stand for whole body irradiation and confirmed to assist patient setup giving sedatives. Then accomplished the authorizing and quality assurance (QA) procedures for applying a modified Stanford method by applying this rotating harness system to location of pediatric patients at sedated condition and exposed the whole body surface to electrons, the author approved the ability to assignment the system on a modified TBI stand is interesting for clinical application and used for the treatment of two pediatric patients successfully [7].

Lying-on-the-floor is another modification in Clinical application of total skin electron irradiation for frail patients with the applying of a custom-built copper flattening filter to develop treatment area homogeneousness, which excludes the requirement for field junction and decreases setup period [8].

Two reviews were published concerning this technique, 1st in 2013 which discussed its technique, method and practical steps of application with fractional scheme. The 2nd review concerned with in-vivo dosimetry during TSEI [9]. In the same year a dosimetric comparison of using 4MeV vs 6 MeV for TSEI and revealed the suitability of using 4 MeV without or 6MeV with dose degrader of 0.4mm thickness [10]. Another comparative study included three centers from UK. With 3 different room dimensions, fractionation scheme and MU as well, the study finally assured the importance of performing complete dosimetry before the application of TSEI in Stanford technique [11].

A preliminary comparison of TSEI treatment techniques was performed in UK investigating the difference between six treatment techniques used in four centers in the UK and although there is some differences in the route of dose dissemination among various TSE treatment regimens and definitely the phantom could be applied in a more widespread inter evaluation. The range of penetration can be determined during the clinical practice, so, the rate of penetration varied according to the degree of illness [12].

The aim of this paper was to present a full description of total skin electron irradiation applied without cone, the dosimetry steps, Patient-specific in-vivo QA and monitor time calculations.

Guidelines for total skin electron irradiation

Recommendations of the EORTC [10], dose distribution homogeneity of the ventilation in the place of treatment plane, where an air should be more than ±90 %. The pollution of photon in treat ray of the electron must be equal or less than 0.7 Gy. The detachment amid the linear accelerator window and surface of the subject should kept in the level of 3 m to 8 m.

Radiotherapy of skin surface by applying TSEI technique, the total dosage must be ranged from 31-40Gy [10], whereas, the period of treatment with radiotherapy should be continued from 6 to 9 weeks, depending on the determined doses and the irradiation provided 4 fractions/week in with equivalent dose of 3 Gy to 4 Gy with intermittent periods. The absorption of 80% of the determined prescribed dose should be not less than 4 mm in depth. Whereas, not more than 20% of the dose can be absorbed at 20mm depth. Minimal energy of electron radiation used should range from 4 MeV to 8 MeV during electron radiotherapy [11].

2. Material and Methods

In current study using Varian model 2300CD dual energy linear accelerator having a special attachment which delivers electron at a very high dose rate (10 Gy/min) at the standard surface skin distance (SSD). The high dose rate mode delivered 6 MeV electron beam with acceptable beam uniformity, adequate depth dose while maintaining a low-level of X-ray contamination. The treatment technique remained same as in conventional TSEI and polystyrene screen was used. All patients were administrated a total dose of 36 Gy over 9–14 weeks with a daily fraction of 120 cGy, with a booster dose of 10 Gy to scalp, perineum and sole. Ionization chamber parallel plate chamber (ROOS) for measurements of the prescribed skin dose in the phantom were obtained at the lateral margins, dorsum of the foot, perineum and scalp to see if there are certain hot spots over any skin curvatures were evaluated according to a fixed schedule according setup described in Figure (1) and for phantom using at standard. SSD. Figure (2): setup for phantom measurent for upper and lower irradation.

The dosimetry of TSEI as prescribed in previous literatures performed in 3 steps: Film Irradiation to evaluate depth dose curve, then Ion Camper measurements to calculate required monitor unit for dose delivery, and beam profiles with angle evaluation to achieve the optimum coverage and finally for in-vitro dosimetry we Irradiated the radiographic film when sandwiched inside PTW Iso-check Phantom since our center do not have Humanoid phantom.

For complete evaluation of electron's penetration ability and uniform dose pattern the two characteristic curves were measured at this irregular treatment condition, first the penetration ability was measured as a percentage depth dose curve, and the uniformity of dose coverage performed by measuring beam profile.

The percentage depth dose for electron 6 MeV was measured through irradiating Radiographic films at 3 different conditions: 1st at SSD 100 cm with radiographic film sandwiched in between solid-water phantom, another film irradiated at the maximum extended distance without placing scroider in front of beam incidence, the 3rd irradiation condition was the exact treatment condition. This is to be able 1st to track the changes of basic beam characteristics, 2nd to assure the effect of scroider regarding increasing superficial dose and sparing deeper tissues.

Then for **beam quality determination** a parallel plate PTW ROOS Ion Chamber was placed in the plane of the patient in the air, at the center of light field perpendicular to the beam, distant 283 cm from the focus and then irradiated with a 6 MeV electron beam. Solid water plates were placed in front of the chamber and changing the plate thickness, it was obtained the gradual variation of absorbed dose as function of depth in solid water. The same measurements repeated for Farmer IC. 6MeV at distance extended up to the end of treatment room (2.83m)

3. Results and Discussion

The linear accelerator is equipped with a high dose rate electron beam for one selective electron energy for treatment protocol which allows for TSEI delivery. the number of monitor units released by the machine per minute (mu/min) is the rate of electron radiation at high dose. The rate of electron radiation is equal 400 mu/min in case of standard treatment protocol, while it reached 1000 mu/min during treatment of TSEI.

One monitor unit represents one centi-gray (cGy) during adjustment of linear accelerator, therefore, the rate of dosing in case of TSEI regimen is about 10 Gy/min, given 3 times, where the dose of 3Gy/min each time for standard condition for treatment. On the other hand, it should be observed that the previous dosage are calculated for standard conditions supposing dose quantity at SSD of 100cm used in the case of classic treatment regimens.

As shown Figure (3). There is no significate difference between PDD for standard energy and High dose rate (10Gy/min) and there no difference in value x- ray contination between two PPD curves.

Figure (1): The setup for Humanoid Phatom in upper and lower position for gantry rotation respectively and phantom for measurement.

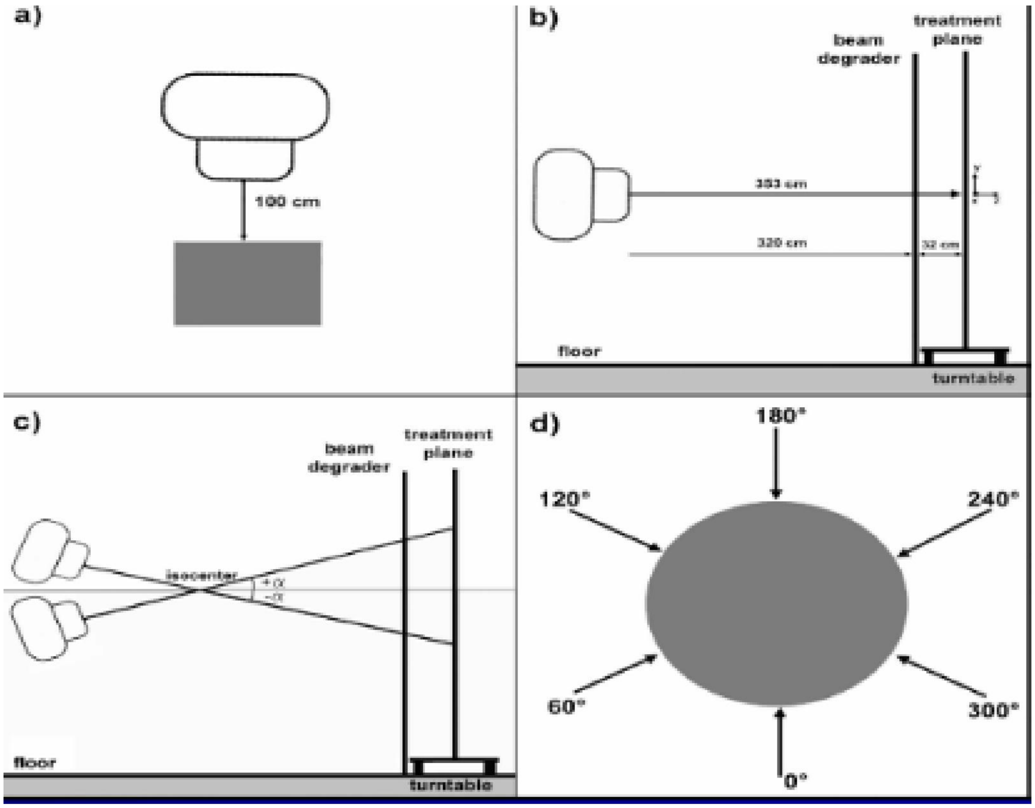


Figure (2) Beams arrangement and Angle for gantry rotation for upper and lower irradiation.

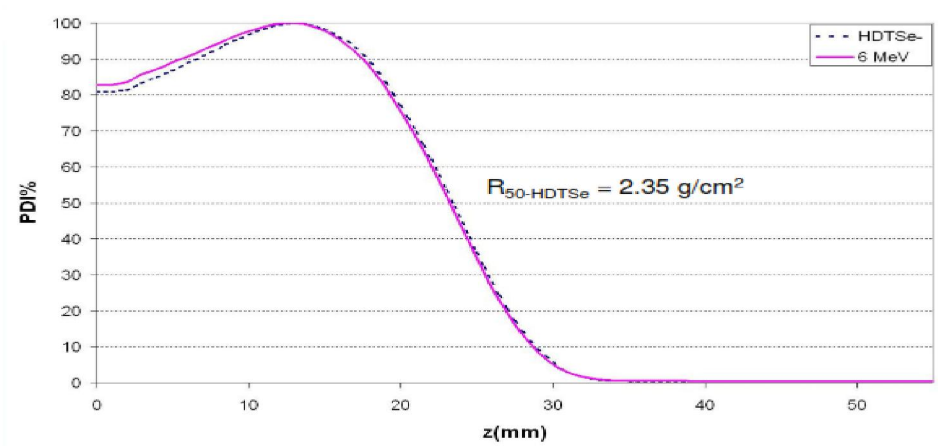


Figure (3): Perecntage Depth Dose (PDD) for standrad 6MeV electron beam and High Dose 6MeV electron using in TSI technique.

Table (1) Effective SSD as a function of Field Size (Applicator) and Energy

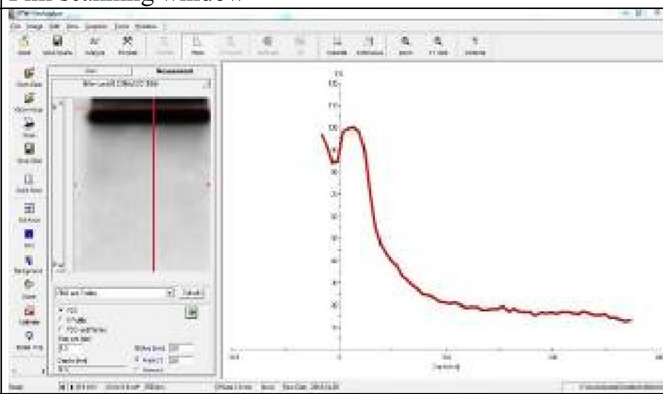
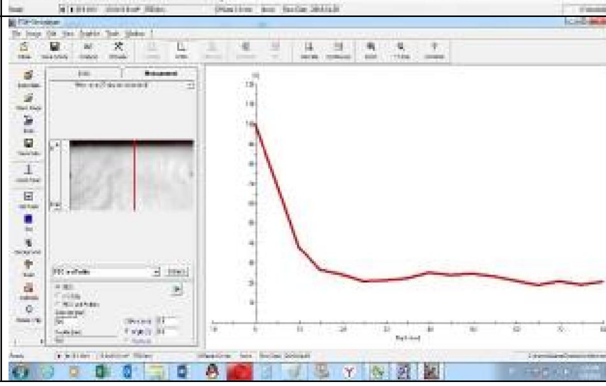
	6*6	10*10	15*15	20*20	25*25
6 MeV	118.90	82.16	88.60	90.03	90.99
8 MeV	77.56	86.34	88.75	90.76	91.46
10 MeV	117.13	86.34	89.28	90.53	91.48
15 MeV	84.66	87.14	89.66	91.79	92.87
18 MeV	80.17	83.72	88.63	91.59	92.91

The depth dose curve with significant increase of surface dose at treatment position with scroider and the limitation of dose to be superficial.

Table (2) Absolute dose Calculated Vs Measured at extended distances: -

Factor energy	Virtual source dist.	Extended distance (cm)	Dose rate (cGy/MU)	Calc. dose/100MU	Measured (ROOS IC) (mean ±SD)
6 MeV	86.6	100	0.9967	99.7	99.6 ±0.57
		105	0.9806	89.1	89 ±0
		110	0.7998	80	80 ±0
		115	0.7216	72.2	71.33 ±0.57
		120	0.6537	65.4	64 ±0
		140	0.4490	44.9	43 ±0

Table (3): The condition for electron beam using film dosimetry system.

Film Irradiation condition	Fim scanning window	PDD Charactics	
6 MeV at SSD 100cm		R_{100} R_{80} R_P	 1.57 2.2
6 MeV beyond scroider		R_{100} R_{80} R_P	 0.44 0.4

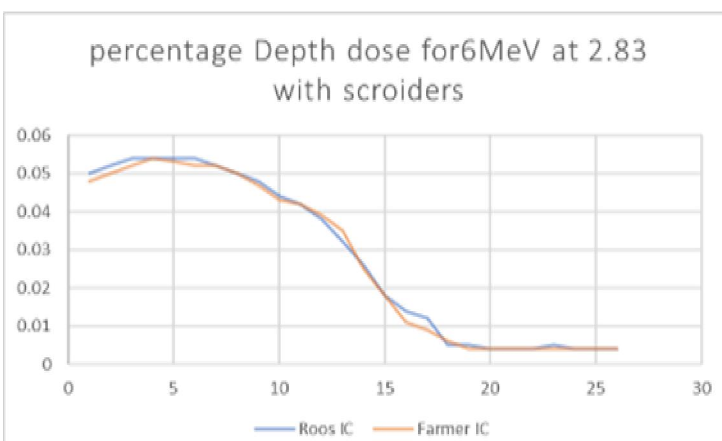


Figure (4): The PDD Curve measured with two different Ion chambers at the treatment position of TSEI

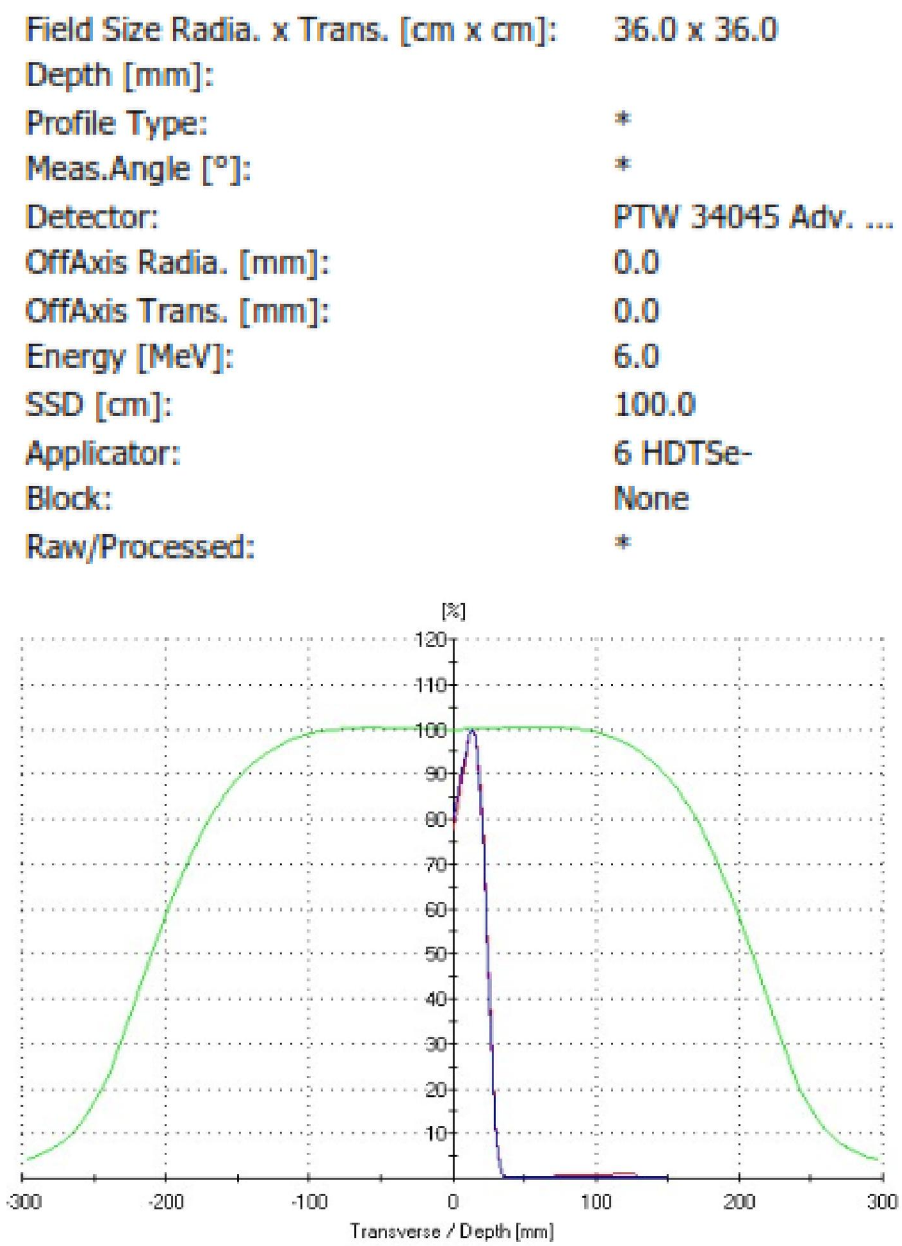


Figure (5): The profile for 6HDTSe MeV and PDI and PDD high dose rate.

As illustrate in table (4). The beam characteristics at gradual extended distances was compared to the nominal profile at SSD 100cm, the significant variation appeared as the deviation from central axis increased 24 times at SSD 140 compared to nominal distance. The field size increased, as well, following the inverse square low with significant increase in both penumbra Lt and Rt and decrease in measured dose. Other factors such as beam symmetry, maximum dose and minimum dose which indicate the suitability of treatment at extended distance with additional dosimetric considerations are required as SSD extended.

Table (4) Electron 6MeV beam characteristics at extended distance

SSD (cm)	**100**	**105**	**110**	**115**	**120**	**140**
CAX Dev. [mm]	-0.22	-0.79	-1.56	-2.29	-2.84	-5.42
Field Size [cm]	10.6	11.085	11.667	12.282	12.862	15.343
Pen. Left [mm]	15.51	19.76	22.7	27.19	32.26	52.21
Pen. Right [mm]	15.28	19.43	22.87	27.48	31.95	51.54
Dmax [%]	100.03	100.05	100.08	100.12	100.12	100.17
Dmin [%]	96.28	96.28	96.12	95.8	95.52	94
Dave [%]	98.3	98.2	98.37	98.25	98.13	97.68
Flatness [%]	103.9	103.92	104.12	104.51	104.82	105.69
Symmetry [%]	101.08	100.7	100.64	100.83	100.85	100.74
Point Distance [mm]	12.80 12.23	15.42 |14.30	18.68 |17.18	22.13 21.01	25.28 24.58	38.17 37.61
Max.Dose Ratio	1	1.001	1.002	1.002	1.002	1.003
Field Size at SID [cm]	10.6	11.085	11.667	12.282	12.862	15.343
F80 | F90 [mm]	9.16 9.58	9.20 |9.67	9.60 | 10.41	10.49 11.88	11.75 13.11	14.90 16.32

Matched Fields: -

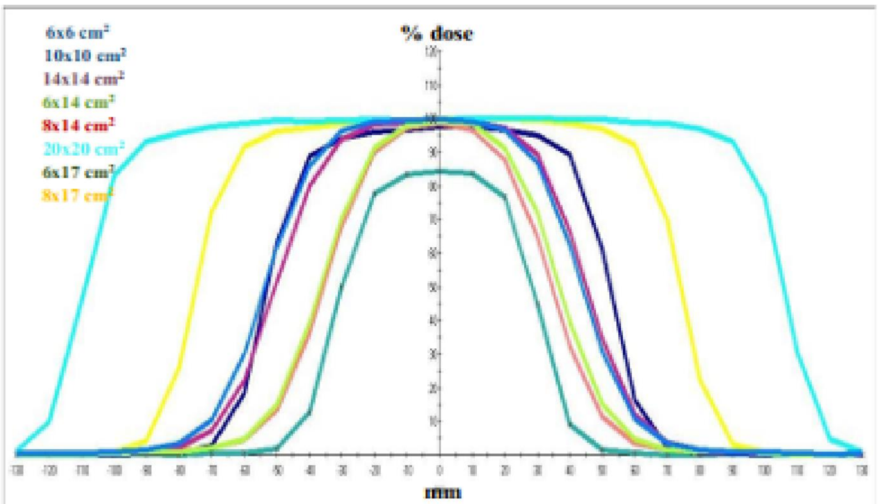


Figure (5): Beam profile of 6MeV at different field dimensions in Lt/Rt direction.

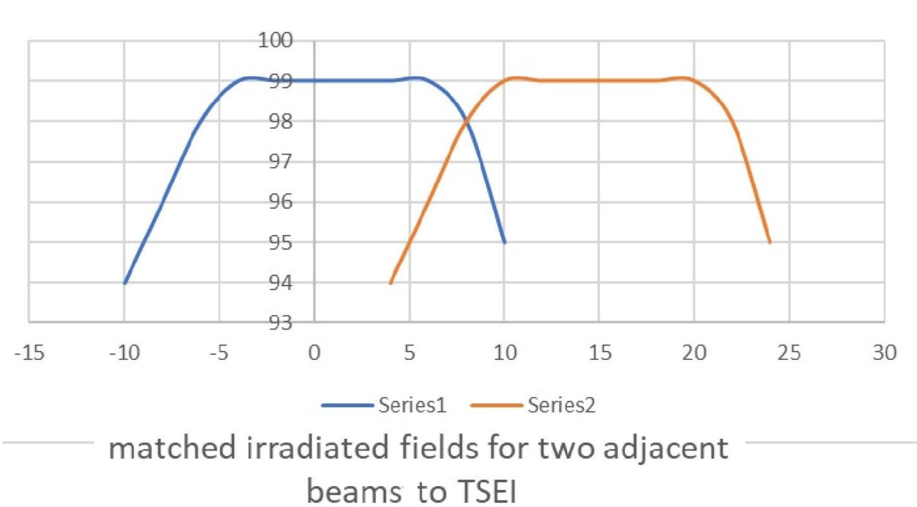


Figure (6): Matching between two adjacent electron fields

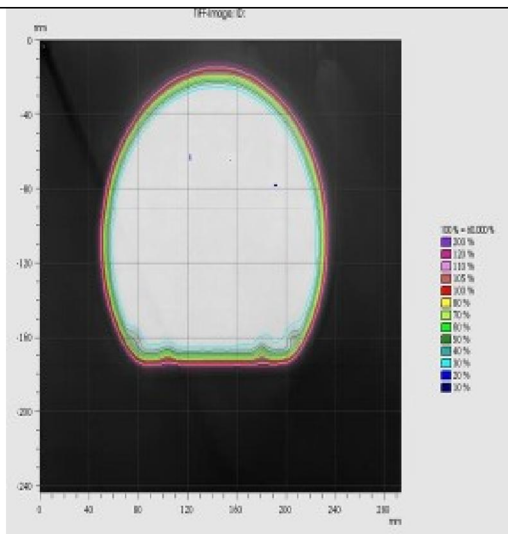
R50 = 1.25cm
E0 = C x R50
E0 = 2.33 MeVcm-1 x 1.25cm = 2.91 MeV
-The absorbed dose at 4mm depth (d_{max}) was calculated and corrected according to AAPM task group (21) as follows:
$D\ poly/U = M/U\ X\ Ctp\ X\ N_{gas}\ X\ (L/P)poly\ air\ X\ P_{repl}\ X\ P_{ion}\ X\ P_{wall}$
$D\ water/U = D_{poly/U}\ X\ (S/P)_{poly\ air}\ X\ \Phi_{poly}$
.

As show in fig (There is a small variation between the reference field size and the irregular lead cutout for low electron energy. Also, profile parameters for the small lead cutout varied from the reference field size when one of the field dimensions is smaller than the practical range of the electron energy used. The variation in the output factor for rectangular lead cutouts and its equivalent square field, size decreasing by the field dimension increasing [12].

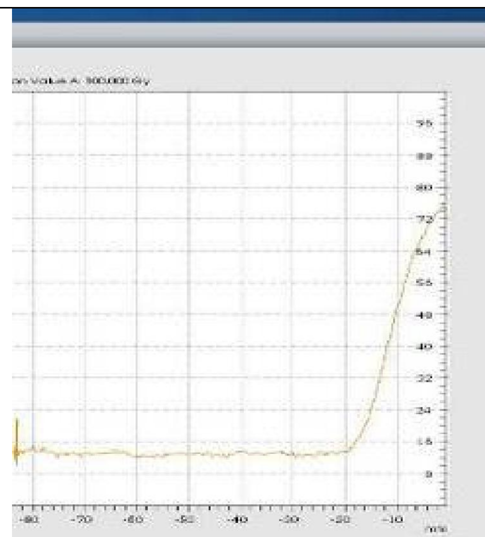
The ability to insert parameters considering irregularity of electron field into planning system may help predict dose coverage as well.

Tumours bed irradiation in standard conditions within a 2-cm margin was adequate within standard conditions of irradiation. Extra margin was required with field width smaller than 0.8E. The same energy was taken when high electron energies were selected because the higher stability of energy. However other studies considered the high electron energy coverage at depth is more difficult to maintain with breast curvature as example [13].

The application of TSEI must be performed after dosimetry of beam energy pre-treatment and in vivo to check dose distribution along the body curvatures.



The irradiated field with uniform dose distribution all around the surface



Dose scaling represent maximum dose within a cm and fast degrading dose deeper

Figure (7): The beam at nominal distance, extended distance and treatment position examined with irradiated film shown in Figure (7).

Conclusion:

The application of Total Skin Electron Irradiation Technique is applicable even without adding applicator to the gantry, however the complete dosimetry required for each treatment machine and mandatory for accurate application of the technique especially with narrow range of treatment.

In Total Skin Electron irradiation (TSEI), the treatment position was different then PDD curve and beam profiles were measured. The maximum skin dose achieved with 6MeV when scroider in front of patient at maximum extended distances with patient at stand-up position. The monitor unit was calculated based on the dose calculated at the same position. The dose uniformity must be also checked to apply in vivo dosimetry and film scanning to the whole applied fields.

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5/21/2019