

Comparison of Dose Measurements Using Different Techniques and Calculation by Treatment Planning System

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ABSTRACT

The aim of the present work is to gain an accurate calculation of dose for small field dimensions and performing this task by evaluating the accuracy of planning system calculation. The obtained results will be compared with real measurement of dose for same small field using different detectors. Methods were carried out through two stages: (i) Determination of some physical factors required for dose estimation measured by three ionization chambers and calculated by Treatment Planning System (TPS) based on the latest technical report series of International Atomic Energy Agency (IAEA), (ii) A comparison of calculated and measured data was done. The obtained results showed that for small field area irradiated by high photon energy was matched with that obtained by ionization chambers and TPS. Radiographic films were used as additional detectors for the obtained data and showed agreement as well with TPS calculations. It can be concluded that for small field dimensions, the difference between calculations by TPS and measured values by Ionization Chambers (IC_s) at 6 MV was averaged to 6% and at 15 MV, to 4%. Radiographic film measurements showed a variation in results within $\pm 2\%$ than TPS calculations.

Keywords: Radiotherapy (RT), Treatment Planning System (TPS), Ionization Chamber (IC), Radiographic Film (RF).

INTRODUCTION

Human tissues are considered similar to water in terms of their constitutes as adult contains from 50-70 % of water. For this reason, irradiation doses prescribed to cancer patients typically referred to doses in water. Essential for small field dosimetry is linking clinic measurements to standard parameters, so that the measured data are converted to absorbed dose in water [1]. The basic rule in radiotherapy is to ensure that uncertainty in the dose received by a patient does not exceed 5%. Considering all sources of uncertainty, this means that the dose at the calibration point of a linac has to be determined within 2%.

The definition of a small field in radiation dosimetry is currently very subjective and ad hoc. There is no clear consensus definition as to what constitutes a small field. Commonly, a field area of less than $3 \times 3 \text{ cm}^2$ is considered to be outside the conventional treatment of field area that needs a special attention in both dose measurement and calculations. A more precise approach is needed to set the criteria which define a small field condition based on the beam energy and the density of the medium [2].

There are basically three equilibrium factors that determine the scale of the field as small:

1. Dimensions of beam when projected upon the detector.
2. Suitable dimensions of detector used in measurements.
3. Small scattered radiation due to small field dimensions.

Treatment planning system commissioning requires the input of beam data specific to the treatment units. This requires the acquisition of depth dose profiles, beam profiles and relative dose factors [3]. The difficulty in achieving accurate small field dose measurements is similar to factors which affect specific measurements in the dosimetry of larger fields (e.g. the steep dose gradients in penumbral regions and the loss of charged particle equilibrium in the build up region) but they are accentuated. The loss of lateral charged particle equilibrium generally results in a decreased dose at central axis, rather than at the beam edges and the build up regions. In addition, the narrowing of the beam results in a more peaked lateral dose profile, which escalates the requirement for higher spatial resolution not only in the penumbral regions, but also at the central axis.

Experimental Techniques:

(1) Instrumentations:

Linear accelerator – Elekta model – high energy (dual energies) 6 and 15 MV photon beams was used .The treatment planning system used in this work is Xio planning system. Dosimeters employed were :1-Farmer ionization chamber ,2-vented cylindrical ionization chamber for measuring high-energy photons, in water or in solid-state material,3-Semiflex chamber (0.125 cm³),4- Pinpoint chamber (0.015 cm³). The type of waterproof chambers have been specially designed for relative beam profile measurements . The Pinpoint chamber is ideally suited for measurements of small fields of inner diameter 2.9 mm. Farmer dosimeter model (2570 / 1B), and radiographic Film model Kodak X-OmatV were used.

(2) Methods:

By using Elekta model linear accelerator to determine the absorbed dose, mechanical check should be initially followed to ensure the suitability of the machine to perform the dosimetry measurements. The laser lines compromise the cross wires in the light field area should be checked. The isocentre point for gantry, collimator and couch rotation should also be checked. The water phantom should be adjusted at 100 cm SSD, and locating the IC at 10 cm depth for 6 & 15 MV photon beams with 90 degree gantry angle, zero degree collimator angle and zero degree couch angle according to IAEA protocol (TRS 398).Measuring pressure and temperature to calculate the factor $K_{T,p}$ which

estimate the effect of both pressure and temperature on measurements . Different small fields were irradiated and absorbed dose should be measured for each field. Results obtained by TPS were compared with practical data of IC_s.

Choosing standard films to be the reference doses, by irradiating different films gradually from 20 to 100 monitor units. Where the irradiated films placed in the Perspex sheets at the depth of maximum dose for each beam energy (1.6 cm for 6 MV & 2.7 cm for 15 MV),The absorbed dose can be determined for each irradiated film according to relationship between optical density and absorbed dose. Irradiated small fields and measured absorbed dose were compared to results of TPS data.

Results and Discussion

(A) Dose Measurement by different ionization chambers:

(a)- Small Fields Irradiated by Beam of Energy 6 MV:

The calculated data of absorbed dose taken by the treatment planning system versus the measured data for the three ionization chambers were presented in table (1), three types of ionization chambers (farmer, pinpoint, and semiflex) were used for different dimensions at reference depth of 10 cm with respect to small field for 6 MV.

Fig. (1) shows the comparison of results calculated by TPS and measured values of 6 MV for different small fields started from 2x2 to 4x4 cm² at 100 cm SSD, and at reference depth of 10 cm in a standard phantom.

Table 1: Measurements of doses by different IC_s and TPS for 6 MV.

Field area cm ²	TPS (Gy)	farmer (Gy)	pinpoint (Gy)	Semiflex (Gy)
2x2	0.557	0.375	0.315	0.281
3x3	0.585	0.565	0.532	0.511
4x4	0.608	0.603	0.588	0.565

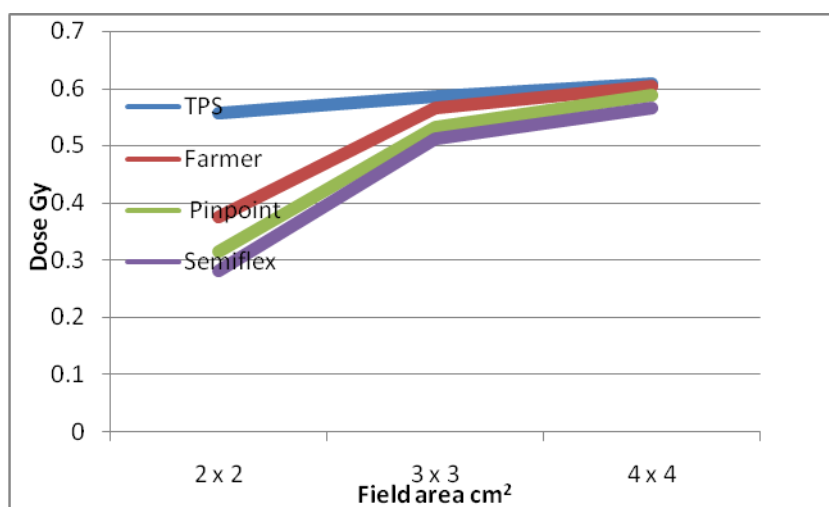


Fig. 1: Variation of doses due to irradiation of small fields.

The comparison of the calculated data by TPS and measured doses with ionization chambers describes the difference between calculated and measured data in two points. First one represents difference between the calculations by TPS and that which measured by ionization chambers for small fields (3x3 and 4x4 cm²) this difference is averaged to 6% for all used ICs in present study. Second point, shows difference which is averaged to 4% between the calculated data by TPS and measured by ICs for 2x2 cm² field.

The measured doses in standard phantom were less than that of TPS values for small field of area less than 3x3 cm². This underestimation is due to

electronic equilibrium which is not sufficient for fully scattered photons from linear accelerator for beam of energy 6 MV [4].

(b) *Small Fields Irradiated by Beam of Energy 15 MV:*

The calculated data of absorbed dose taken by TPS versus the measured data for three ionization chambers are presented in table (2), The three types of ionization chambers were used for different fields at reference depth 10 cm relative to small fields for 15 MV.

Table 2: TPS data versus the measured doses by different ICs for 15 MV.

Field area cm ²	TPS (Gy)	Farmer (Gy)	Pinpoint (Gy)	Semiflex (Gy)
2x2	0.617	0.503	0.282	0.299
3x3	0.655	0.637	0.598	0.607
4x4	0.686	0.682	0.669	0.698

Fig: (2), shows the results of comparison for calculated data by TPS and measured doses for beam of energy 15 MV for different small fields started

from 2x2 to 4x4 cm² at 100 cm SSD, at reference depth 10 cm in a standard phantom.

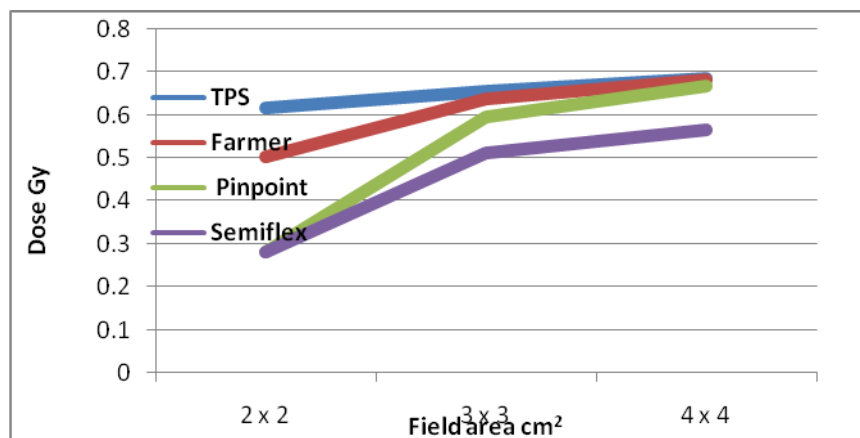


Fig. 2: Change of doses for small irradiated fields.

The Discrepancies between calculated data and measured doses were observed in two cases. First one represents difference between the calculated data by TPS and measured doses by ICs for small fields (3x3 and 4x4 cm²) were averaged to 4% for the three types of ICs used in present work. These data are in agreement with data published by Agostinelli *et al.*, [5] with an average variation of 3.8 %. Second case, illustrates difference which exceeds the average by 4% between TPS and measured doses using ICs for field of 2x2 cm².

(B) *Dose Measurement by Radiographic Films (RFs):*

Measurement of dose by irradiation of X-OmatV films was performed for both energies 6 and 15 MV.

(a) *Small fields exposed to Beam of Energy 6 MV:*

The calculated data of absorbed dose taken by TPS versus the measured doses by radiographic films were represented in table (3) for different small fields (2x2, 3x3 and 4x4 cm²) at D_{max}. 1.6 cm for 50 MU.

Table 3: Measurement of doses using radiographic films and TPS for 6 MV.

field area cm ²	TPS cGy	RF cGy
2x2	44.65	43.8
3x3	45.65	46.35
4x4	46.56	49.83

Fig.(3) indicates minute differences between the TPS and the experimental measurement for small fields 2x2 and 3x3 cm², these differences within $\pm 2\%$ due to good accuracy of treatment planning system. These data is in agreement with results obtained by

Garcia-Vicente *et al.*, [6], their difference was within $\pm 1.5\%$. For field area 4x4 cm², the measured data increased within 6% at 6 MV. This is due to the quantity of scattered radiation which is directly proportional to field area.

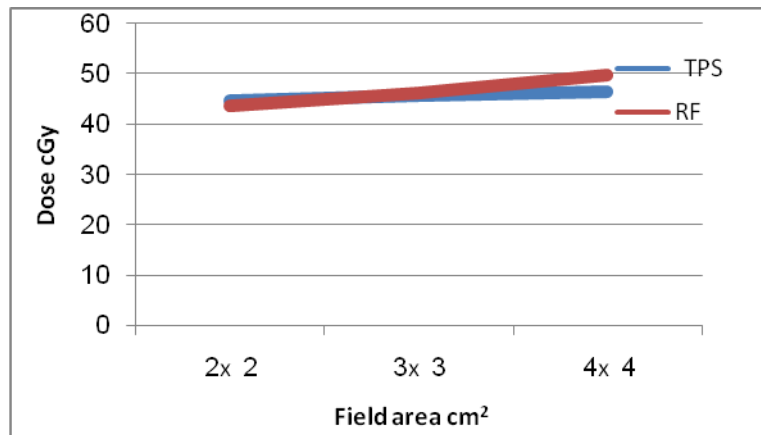


Fig. 3: Minute variation of dose by radiographic films.

(b) *Small fields exposed to Beam of Energy 15 MV:*

are presented in the table (4) for different small fields (2x2, 3x3 and 4x4 cm²) at D_{max} , 2.7 cm and 50 MU.

The calculated data of absorbed dose taken by TPS versus the measured data by radiographic films

Table 4:Records of doses by radiographic films for 15 MV.

Field area cm ²	TPS cGy	RF cGy
2x2	42.71	46.55
3x3	44.15	49.19
4x4	45.65	50.65

Fig. (4), shows small difference between the TPS and the experimental data using radiographic films. These measured data were increased as field area enlarged from 2x2 to 4x4 cm² by a constant value of 5% [7]. Film response error includes processing procedure and an energy dependent of non-linear response. Corrections were applied for response deviations due to the energy dependence,

including response changes due to value of field area and its depth. Processing variation errors were minimized by using a reference calibration film exposed and processed for each experiment. The response relationship between the single film calibration and multi-film central axis should be measured [8].

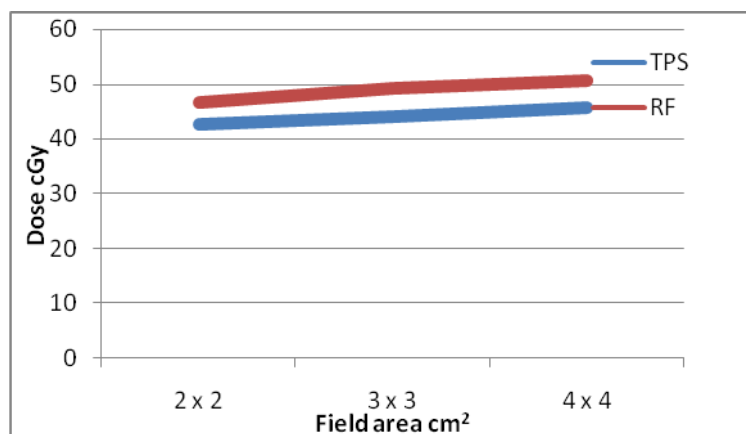


Fig. 4: TPS values versus the measured data by radiographic films.

Conclusion:

- Measured doses in standard phantom were less than TPS values for small fields of area less than $3 \times 3 \text{ cm}^2$, this underestimation is due to an electronic equilibrium which is not sufficient for fully scattered photons from dual energies linear accelerators.
- Field dimensions larger than $3 \times 3 \text{ cm}^2$ have an average difference of 6% for energy of 6 MV while 15 MV showed an average of 4% for the used three types of ionization chambers.
- Measured data by radiographic film for 6 MV showed small difference between the TPS and the experimental data for fields 2×2 and $3 \times 3 \text{ cm}^2$, this difference was within $\pm 2\%$ due to good accuracy of TPS.
- For field area $4 \times 4 \text{ cm}^2$ the measured data increased within 6%. This is due to the quantity of scattered radiation which is directly proportional to field area.
- Mild differences between the TPS and the experimental data were observed using radiographic films for energy of 15 MV. Measured experimental data was increased as field area enlarged from 2×2 to $4 \times 4 \text{ cm}^2$ by constant value of 5%.

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