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STUDY ON THE DISPLACEMENT EFFECT AT CYLINDRICAL IONIZATION CHAMBERS IN HIGH ENERGY PHOTON OF FLAT AND TRUE BEAMS

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ABSTRACT

Absorbed dose to water determination in the clinical practice introduces several perturbations factors in ionization chamber dosimetry. Displacement perturbation is one of them, which can be corrected by introducing the chamber-specific quality correction factor (k_Q) or by introducing the concept of effective point of measurement (EPOM). The EPOM is the point in the chamber at which the measured dose would be the same as the measuring depth in absence of chamber. The aim of this study was to measure the displacement effect at cylindrical ionization chambers in 6 and 10 MV flat and true photon beams. The percentage of depth doses (PDDs) were considered for determining the shift of EPOM with respect to the well established Roos chamber. The displacement effect obtained a range of 0.25 to 0.57 times r (chamber radius) both in flat and true beams, which disagreed with the TRS-398 protocol recommended constant value of 0.6r.

Key words: Cylindrical chambers, displacement effect, photon beams.

INTRODUCTION

Accurate absorbed dose measurement is a very fundamental requirement of successful radiotherapy. Optimum radiation dose to the tumour tissue and minimum dose to the healthy tissue is the goal of radiotherapy treatment. For megavoltage photon beam measurement cylindrical ionization camber is the mostly used ionization dosimeter. In clinical practice radiation sensitive devices (dosimeters) and water as phantom materials are used in dosimetry for dose measurement. The composition of ionization chamber is non equivalent to the water therefore, the measured dose is not equal to the dose that of water.

It was shown by Spencer LV *et al.* (1955) that the determination of the dose to water from the detector signal is based on the chamber cavity. The dose to the cavity produces

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in the water or medium by the radiation sensitive device (chamber) is not equal to the dose to the medium (water). Using of ionization chamber same problem arises: it replaces water equal to the volume of the chamber. This replacement has a certain influence on the dose determination which is referred to a “replacement effect” or displacement effect.

This displacement effect requires special consideration particularly at cylindrical ionization chambers dosimetry. It was explained in the published paper by Andreo O *et al.* (2000) and Skaggs LS *et al.* (1949) regarding the displacement effect. According to the authors, the correction of this effect is possible to be compensated by two alternative ways. One is by multiplying the displacement perturbation factor (P_{dis}) and another one is to put the EPOM of the chamber on the depth of interest on the central axis of the radiation beam. Kawrakow (2006) showed that, the effective point of measurement (EPOM) plays an important role in relative dosimetry in megavoltage photon beams. Taylor and Francis (2007) also showed the importance of the correction of effective point of measurement. The shift of the chamber is possible to use to do the correction during chamber set up for accurate dose measurement. Shimono T *et al.* (2007) again calculated the effect for the correction of displacement effect in dosimetry. The displacement effect is the shift of EPOM divided by the chamber radius of the used cylindrical chamber. The shift of EPOM is possible to measure by measuring the PDD (percentage depth dose) curve of experimental cylindrical chambers and the reference chamber (Roos chamber).

The photon beams coming out from the linac (linear accelerator) head after interacting with flattening filter is called flat beam and the beam coming out without the interaction is called true beam. The flattening filter is composed of steel, which makes the beam intensity uniform in the exposed field due to its construction. In true beam the dose rate is higher than that of flat beam and the beam intensity is not uniform like flat beam in the exposed field. The objective of the study was to measure the displacement effect at cylindrical chambers in 6 and 10 MV flat and true beams by measuring the relative dose PDD for cylindrical ionization chambers and Roos chamber.

MATERIALS AND METHODS

Linear accelerator (Elekta Versa HD,) Roos chamber, specially designed cylindrical chambers (six in number), Semi-flex chamber and water phantom (IBa blue phantom) were used for the study. 6 and 10 MV flat beam and true photon beams were considered in this experimental study.

Measurement was performed with six Farmer typed (cylindrical) chambers with inner radius, ranging from 1.0 mm to 6.0 mm. These chambers were water proof and types were TM 30013.1.911, 30013.1.921, 30013, 30013.1.941, 30013.1.951 and

30013.1.961, PTW Freiburg, Germany. For all cylindrical chambers the cavity length was 23 mm, the wall was made up of PMMA (poly-methyl methacrylate) with a thickness of 0.335 mm and covered with an additional thin graphite layer of 0.09 mm, the central electrode was of aluminum with a diameter of 1.15 mm. The chambers were referred as R1, R2, R3, R4, R5 and R6. The volume of Semi-flex chamber was 0.35 cm^3 with 2.75 mm inner radius. The plane parallel Roos chamber (type 34001, PTW) and other related instruments used in the study are shown in Fig. 1.

(a) Semi-flex chamber

(b) Linac with water phantom

(c) Cylindrical chambers

(d) Roos chambers

Fig. 1. (a) Semi-flex chamber (b) Linear accelerator, (c) Six cylindrical chambers and (d) Roos chamber

The cylindrical chambers were placed considering the central axis set up on the water surface in the water phantom following mirror imaging system. 100 cm source to surface distance (SSD), 10 x 10 cm^2 field size and vertical radiation beams were considered for the study. For the six special chambers a device was prepared in the experimental lab to hold the chamber in the water phantom, which is shown in Fig. 2. It secured the attachment of the chamber perfectly in the phantom. The chamber setting was started with the smallest (1mm radius) chamber and keeping the holder at the same position for all other chambers to ensure the set up error minimum. The beam central axis measurements were performed in the direction of chamber movement from bottom to the surface of the water in 6 and 10 MV flat and true photon beams.

Fig. 2. Special holder for the special chambers used in the PDD measurement.

The stepping was set 5 mm for the chamber movement. The relative doses, PDDs were measured in the water phantom following the International Atomic Energy Agency (IAEA) TRS-398 protocol. All machine generated data were in the notepad format. The notepad data were transferred to the Excel sheet and converted into excels data for the analysis. The measured ionizations were normalized to the maximum (100%). Omni-Pro 7.2 software was used for the dosimetric measurement. Microsoft Excel and Sigma Plot-10 software were used for the calculation and experimental graph analysis. “Quick transfer” option of Sigma Plot-10 was used to measure the shift of EPOM up to 0.01 mm uncertainty, which is shown in Fig. 3.

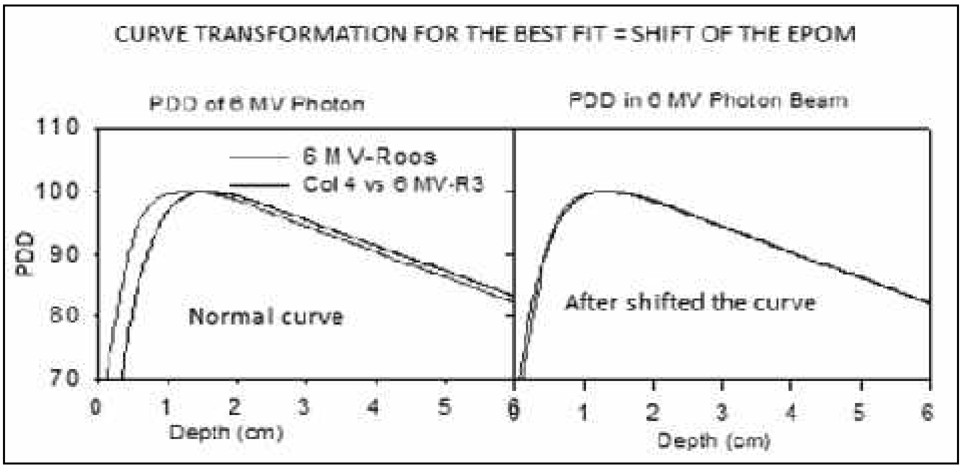

Fig. 3: ‘Quick transfer’ of Sigma Plot-10 shift of the original curve from left to the right.

The best fit of the curves and hair like curves lines were considered for calculating the shift of EPOM. During matching 200% enlarged curves were considered to minimize the human error. It was taken from the difference of the depth between two curves for the same dose with respect to the reference curve (curve of Roos chamber). In Fig. 4 (a) two curves represented the same dose (PDD) with two different depths. The depth difference showed the shift of EOPM. Figure-4(c) showns changing the horizontal scale of 4 (b) to explain the curve differences.

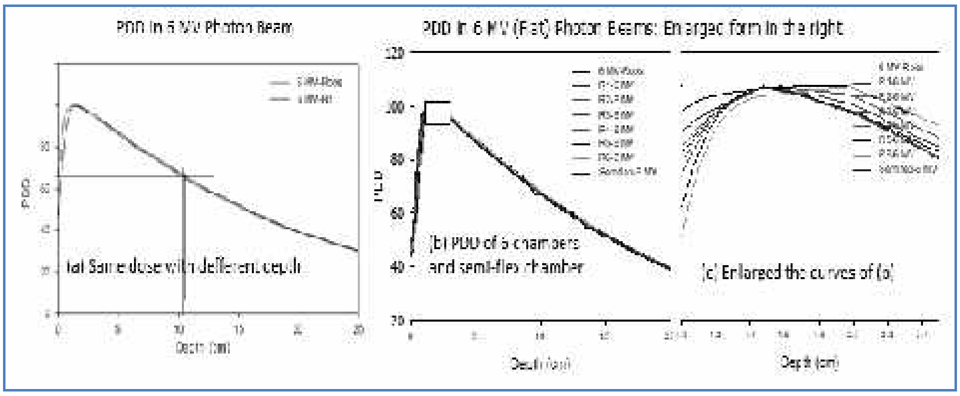

Fig. 4. (a) Same PDD with deferent depth (shift of EPOM) by two different chambers. (b) PDD of all experimental chambers and (c) enlarged curves of (b).

RESULTS AND DISCUSSIONS

The obtained PDD are shown graphically in Fig. 5 for all experimental chambers. The shifts of effective point of measurement (EOPM) at cylindrical chambers vary with beam energy and chamber radius. The experimental displacement effect observed not a constant value but a range of 0.25 to 0.57 times r (chamber radius) both in the flat and true photon beams which is shown in the Table-1. The average experimental values were found lower than that of the recommendation (0.6r) in the TRS-398 protocol, which was a single value. The comparison is shown in the Fig. 6. The obtained displacement effects (shift of EPOM/radius) are presented in the Table-1 in 6 and 10 MV flat and true photon beams. The effect in flat and true photon beams found variation in the results but any conclusion was not possible to draw.

A: The percentage of depth dose (PDD) of six cylindrical, semi-flex and Roos chamber are shown in Fig. 5.

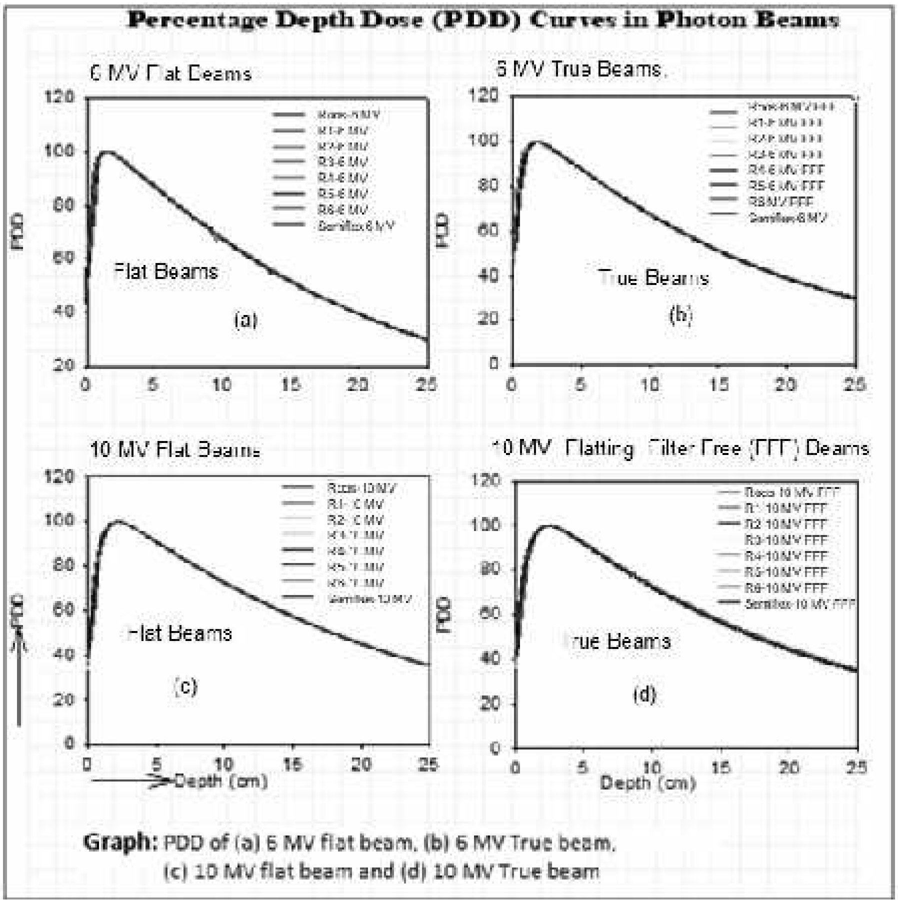

Fig. 5. PDD in 6 and 10 MV flat and true photon beams.

Table-1: The displacement effect at cylindrical chambers in 6 and 10 MV flat and true photon beams.

The shift of EPOM were obtained by Sigma Plot-10 at cylindrical chambers in 6 and 10 MV flat and true (Flattening Filter Free: FFF) photon beams and displacement effects were calculated.					
Displacement effect (shift of EPOM/r)					
Chambers	6 MV (Flat)	6 MV (FFF)	10 MV (Flat)	10 MV(FFF)	
R1	0.40 r	0.30 r	0.50 r	0.50 r	TRS-398
R2	0.25 r	0.40 r	0.45 r	0.45 r	
R3	0.47 r	0.57 r	0.47 r	0.43 r	
R4	0.50 r	0.45 r	0.47 r	0.50 r	
R5	0.52 r	0.52 r	0.50 r	0.52 r	
R6	0.46 r	0.52 r	0.50 r	0.53 r	
Semi-flex	0.40 r	0.47 r	0.40 r	0.40 r	
Average	0.43 r	0.46 r	0.47 r	0.48 r	

B: The Displacement Effect Comparison with TRS-398 Protocol:

The comparison of displacement effect was represented in the Fig. 6 graphically. The experimental values were found lower than that of TRS-398 protocol.

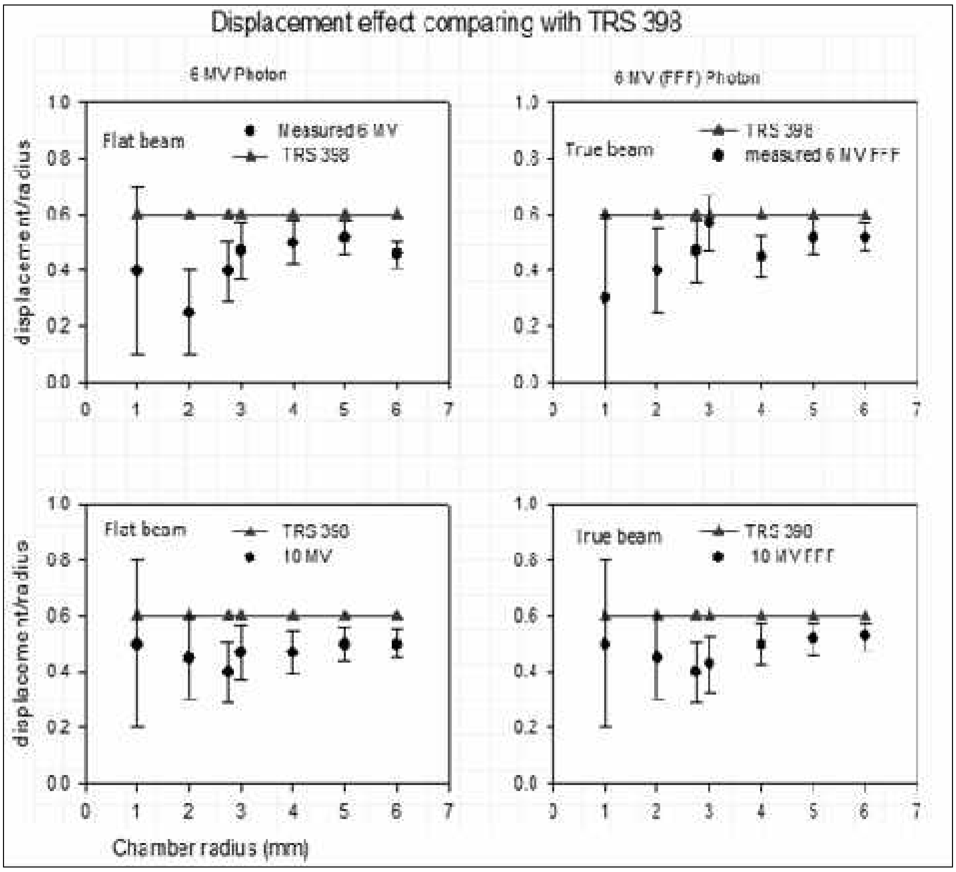

Fig. 6. Comparison of displacement effect with TRS-398 prtocol.

In the plane parallel chamber (Roos chamber), the position of the EPOM is at the inner surface of the entrance window at the center of the opening window in radiation beams. The positioning of the Roos chamber was placed -1.5 mm (minus sign indicates toward the radiation source) so that the EPOM was on the measuring depth in the water phantom. This value is well established and is published. The meaning of measuring depth at z is equal to $z_m + d_f - d_{eq}$, where z_m is measuring depth, d_f is the thickness of the entrance window and d_{eq} is it's water equivalent thickness using the ratio of the densities of water and entrance window materials.

A few studies aiming to the reduction of the uncertainty related to the exact positioning of the EPOM are available with respect to the Roos chamber it was found that the more accurate positioning of EPOM was given by a distance of 1.5 mm above from the front surface of the chamber.

The well established Roos chamber was carefully set as –1.5 mm from the front surface of the chamber and was taken as the reference measurement depth for the study. Firstly it was set exactly on the water surface and then it was lifted 1.5 mm above by the controller. Then the position was saved as zero. The comparison of displacement effects between IAEA, TRS-398 protocol and measured results were shown in Fig. 6. The graph showed that the experimental results are below the TRS-398 recommended protocol in all the energies for flat and true beams. The results were considered after the dose maximum (z_{max}). Therefore, this investigation showed that the uses of EPOM need rethinking for clinical practice. It gives more correction is required for the use of EPOM in dosimetry. Measurement of EPOM and chamber specific Monte Carlo simulation can give an alternative to this solution.

CONCLUSION

The experimental displacement effect appeared to be dependent on beam energy and the chamber cavity but independent on depth after the depth of dose maximum (D_{max}). A recommended single value of displacement correction factor of the protocol does not satisfy this experimental study. Therefore, measurement of displacement effect as well as Monte Carlo simulated displacement effect could be a better solution for the use of displacement effect for a specific cylindrical chamber in the clinical practice.

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REFERENCES

Andreo, O., DT Burns, K Hohlfeld, MS Huq, T Kanai, F Laitano, V. Smyth and S. Vynckier. 2000. Absorbed dose determination in external beam radiotherapy. An international code of practice for dosimetry based on standards of dose to water. *Technical Report Series TRS-398*, Vienna. International Atomic Energy Agency (IAEA). pp. 75-79.

Kawrakow, I. 2006. The effective point of measurement in megavoltage photon beams. *Med. Phy*. **33**: 1829-39.

Shimono, T, H Nanbu, K Koshida and Y Kikuchi. 2007. Analysis of the effective point of measurement of a thimble chamber dosimeter set parallel to the X-ray beam axis. *Igaku Butsuri*: pp.17-25.

Skaggs, LS. 1949. Depth dose of electrons from the betatron. *Radiology* **53**(6): 868-74.

Spencer, LV and FH. Attix. 1955. A theory of cavity ionization. *Radiat Res*. **3**(3): 239-55.

Spencer, LV and FH. Attix. 1955. A cavity ionization theory including the effects of energetic secondary electrons. *Radiology* **64**(1): 113.

Taylor & Francis. 2007. *Mayles P and Nahum A; Hand book of radiotherapy physics. Theory and Practice.*, New York, London: pp. 90.

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