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Effect of Different SSDS and Oblique Beam Incidences on Surface Dose Measurements

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Abstract: ***Introduction**: The purpose of this study was to measure the surface dose and its effect for different source to surface distances (SSD) and oblique beam incidences for 6 MV, 10 MV and 15 MV photon beams using parallel plate chamber. **Material and Methods**: All measurements were conducted in a water equivalent Polymethyl Methacrylate (PMMA) slab phantom under machine-specific reference conditions. Markus type parallel plate ionization chamber with fixed separation between collecting electrodes was used to measure the surface dose. The Markus type parallel plate chamber over-responds on the surface which was corrected by the Gerbi's formula. Results: It was found that as the SSD increases surface dose is decreases and vice versa, also this effect is significant for higher energies. The surface dose increases from the normal incidence with increasing angle of beam incidence which is due to additional forward scattered electrons from the phantom reaching to the point of measurement. The surface dose increases to twice its value near 60° oblique angle compared to 0° angle of incidence. **Conclusion**: The surface dose is clearly decreases with increase in energy. There is a large difference for surface dose between 6 and 10 MV photon beam but small difference between 10 and 15 MV photon beam. This knowledge of surface dose can be used to prevent and manage potential of acute skin reaction and late skin toxicity from treatments with radiotherapy.*

Keywords: surface dose, parallel plate chamber, megavoltage photon beam

1.Introduction

Photon beams with megavoltage energy range have inhomogeneous dose in the build-up region due to lack of charged particle equilibrium (CPE). The dose reduced in build-up region is commonly referred to as skin sparing effect.[1,2] This skin sparing effect is an important advantage in high energy photon beams over orthovoltage and superficial beams in which depth of maximum dose occurs at surface.

The surface dose can be defined as the deposition of energy within small mass of medium at the surface region of the phantom, that is, at the boundary between the air of medium and surface of phantom material.[3] The recommendation for depth of surface dose given by International Commission on Radiological Protection (ICRP) is 0.07 mm (basal layer), and the dermal layer may be assessed at 1.0 mm.[4] International Electrotechnical Commission (IEC) recommends the relative surface dose is measured using a flat radiation detector with successive addition of buildup materials to obtain point-by-point measurements from 0.5 mm to the maximum dose depth.[5] In present study we followed IEC recommendations for surface dose measurements.

In megavoltage photon beams the surface dose associated with radiotherapy is very important for clinical evaluation or investigating for the risk of late effects. However, surface dose is very difficult to measure. The skin is under risk during radiotherapy for effects such as erythema, desquamation, fibrosis and necrosis therefore it is important to study and measure the surface dose. Surface dose in build-up region for megavoltage photon beams is generally much lower compare to maximum dose, which occurs at a depth of D_{max}. Surface dose depends on various factors such as beam energy, field size, source to surface distance and angle of beam incidence. Surface dose is the result from electron contamination of the incident photon beam as well as the backscattered radiation (both electrons and photons) from the medium. There are two sources for contamination: (i) Treatment head parameters such as target, monitor chambers, flattening filter, collimator jaws. (ii) Treatment setup parameters such as wedge, tray, block and SSD.

Generally, radiation field analyzer used for measurements of percent depth dose (PDD) using detectors such as cylindrical chamber or diode. But it is complex task to measure surface dose correctly using cylindrical chamber because of its geometry such as large volume and its structure. In the build-up region there was a steep dose gradient, therefore size of the dosimeter being used along the beam direction should be as small as possible. For surface dose measurement in the build-up region of megavoltage photon beams various detectors such as extrapolation chamber, film, parallel plate chamber, thermoluminescent detectors (TLD), metal oxide semiconductor field effect transistors (MOSFET), diode etc. can be used. Among these detectors, extrapolation chamber is the best detector for surface dose measurement but only few institutions have this chamber.

Instead of extrapolation chamber, fixed separation parallel plate ionization chambers can be used for surface dose measurements, but these chambers over-responds in the build-up region due to large electrode separation. Contamination of secondary electrons which generated from treatment head and setup parameters; they scattering from the sidewall of the chamber and are primarily responsible for the over-response at surface. Several methods have been developed for correction of this over-response of parallel plate ionization chambers for the determination of dose at surface in megavoltage photon beams. Gerbi's correction factor for this over-response in surface region were applicable to all types of fixed separation parallel plate ionization chambers.[1,2] This factor is specific for each chamber design and dependent upon guard size, plate separation and volume.

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The oblique beam incidence of the photon beams reduces the skin sparing effect and increases the surface dose compared to the normal incidence due to additional forward scattered electrons from the phantom reaching to the point of measurement.[6-12] However, for targets close to the skin surface, it is desirable to increase the dose to the surface of the skin. Hence, it is imperative to understand the effect of oblique incidences on the surface.

Secondary electron contamination from the collimator head and beam defining systems increases the surface dose. This effect can be reduced by interposing between the beam-defining systems and the surface. Air can be used to attenuate these secondary electrons by using large collimator to surface distances. However, air itself is a source of secondary electron contamination, and any increase in the volume of irradiated air, by increasing the collimator to surface distance may reduce skin sparing.

The aim of this study is to determine precise surface dose using parallel plate ionization chamber for 6, 10 and 15 MV photon beams for different source to surface distances and oblique beam incidences.

2.Materials and Methods

In present study, surface dose measurements were carried out on TrueBeam (Varian Medical System, USA) linac with dose rate of 500 monitor units (MU)/min using advance Markus parallel plate ionization chamber (PTW-34045 Freiburg, Germany). For Markus parallel plate chamber the physical effective point of measurement was defined as 0.023 mm, at the inner surface of the proximal collecting plate. There is a fixed 2 mm plate separation and sidewall-to-collector distance is 0.35 mm. The relative ionization (PDD) for the points of interest was acquired by dividing the charge collected at any depth by the charge collected at the depth of D_{max} using the PTW UnidoseE dosimeter (PTW Freiburg, Germany).

The measurements of surface dose were carried out using a PMMA plastic phantom ($30\times30\times30$ cm^3) with Markus parallel plate chamber. The PMMA plastic phantom has variable thicknesses of 1 mm, 2 mm, 5 mm and 10 mm having area of 30×30 cm^2 (PMMA, Freiburg, Germany). The phantom has a physical density of 1.190 g/cm^3. All surface dose measurements were carried out with 10×10 cm^2 field size. The procedure was performed according to the IAEA TRS-398 protocol.[13] The parallel plate chamber was operated at a bias voltage +300 V and the chamber was connected to the electrometer through a 20 m long low noise cable.

A parallel plate ionization chamber

Because of the large electrode separation and small guard ring, the Markus type parallel plate ionization chamber in the build-up region over-response, especially at the surface. The over-response of the chamber has been shown to be mainly due to contaminant electrons scattering from the side walls to chamber.

For chamber over-response correction in the build-up region Gerbi's method was used.[14] The over-response of chamber is found by following Gerbi's formula.

$$P'(d, E) = P(d, E) - \xi'(0, E)\, l e^{-\alpha(d/dmax)}$$

$$\xi(0, E) = [-1.666 + (1.982 IR)] \times (C - 15.8)\ (\%/mm)$$

Where,

$\xi(0, E)$ = Chamber factor that dependent on energy and indicates the over-response per mm of chamber plate separation at the surface of the phantom. It was found 5.37% for 6 MV, 3.11% for 10 MV and 2.42% for 15 MV.

The values −1.666, 1.982, and 15.8 are constants and they adopted from the graph, and they represent the % maximum ionization per mm of plate separation at the phantom surface plotted as a function of guard width or collector edge-sidewall distance.[14]

IR = Ionization ratio of the doses at depths of 20 cm and 10 cm, which is measured at a fixed SSD of 100 cm and 10 x 10 cm^2 field size. IR values are 0.665 for 6 MV, 0.739 for 10 MV and 0.763 for 15 MV photon beams, respectively.

P' = Corrected percent depth dose,
P = Measured relative depth ionisation,
E = Energy
D_{max} = depth at which maximum dose occurs,
C = sidewall to collector distance (0.35 mm for PTW-Markus 34045)
l = Plate separation (2 mm for PTW-Markus 34045)
Constant, $\alpha = 5.5$
d = depth of the chamber front window (d = 0 for Surface)
$\xi'(0, E)\, le^{-\alpha(d/dmax)}$ = correction factor was calculated 10.74% at surface for 6 MV, 6.22% at surface for 10 MV and 4.85% at surface for 15 MV.

Relative doses were measured in the build-up region as a ratio of the dose at different depths (ranging from the surface to the depth of dose maximum) to the dose at the depth of maximum ionization in the phantom. For oblique beam measurements, a wooden stand was fabricated to hold the phantom setup at the desired oblique angles. The setup image of truebeam is shown in **Figure 1** for normal and for oblique incidences.

3.Result

Measurements were carried out for 6, 10 and 15 MV photon beams and normalized to 100% at depth of D_{max}. The surface dose measurements were carried out at 0° gantry angle for 80 cm, 90 cm, 100 cm, 110 cm and 120 cm SSDs to verify the effect of surface dose. Also, the effect of surface dose was checked for different beam angles (20°, 40°, 60° and 80°) with 100 cm SSD. Measured data of surface dose for different SSD and different oblique beam incidences are shown below.

Surface dose at different SSDs

Table 1 shows the percentage surface dose results obtained with Markus parallel plate chamber for 6, 10 and 15 MV high energy photon beams for 80, 90, 100, 110 and 120 cm SSDs. Surface dose obtained for 6 MV photon beam were increased by 6.06%, 13.17% for 90 and 80 cm SSDs and decrease by 2.04%, 4.58% for 110 and 120 cm SSDs. Similarly, for 10 MV photon beam were increased by 11.11%, 27.61% for 90 and 80 cm SSDs and decrease by 6.89%, 12.27% for 110 and 120 cm SSDs. And for 15 MV photon beam were increased by 14.64%, 35.81% for 90 and 80 cm SSD and decrease by 8.68%, 15.63% for 110 and 120 cm SSDs. The graph of surface dose versus different SSDs shown in **Figure 2**.

The Field size was defined at 100 cm SSD for all the different SSD clinical setups. The surface dose increases with decreasing SSDs, although this effect is relatively large with increasing energies when SSD decreasing from 100 cm to 90 cm and 80 cm respectively for a field size of 10 x 10 cm^2. Similarly surface dose decreases with increasing SSDs, and this effect is also relatively large with increasing energies when SSD increasing from 100 cm to 110 cm and 120 cm respectively for a field size of 10 x 10 cm^2.

Surface Dose at different oblique beam incidences

Table 2 shows the percentage surface dose results obtained with Markus parallel plate chamber for 6, 10 and 15 MV high energy photon beams for 0°, 20°, 40°, 60°and 80° oblique beam angles. The surface doses at this oblique beam incidence were studied for field size of 10 × 10 cm^2. The graph of the surface dose due to oblique incidences is shown in **Figure 3**. As shown in this figure, the surface dose clearly increases with increasing oblique beam incidence angle. The average surface dose measured with Markus parallel plate chamber increased by 7.23%, 32.60%, 91.24%, 226.46% at incident angles of 20°, 40°, 60°, 80° respectively, for 6 MV. Similarly, 8.22%, 36.80%, 121.32%, 349.60% at incident angles of 20°, 40°, 60°, 80° for 10 MV and 8%, 26.90%, 119.13%, 361.6 % at incident angles of 20°, 40°, 60°, 80° for 15 MV.

The Field size was defined at 100 cm SSD for all the oblique beam angle setups. Dose increases linearly with increase in beam angles. There is a very small difference between 0° and 20° beam angle, although this effect is relatively high near 60° oblique beam angle for all beam energies.

4.Discussion

The surface dose of megavoltage photon beam is mainly from the electrons created by beam of photon interaction at the surface and also from the contaminant electrons which created by photon interactions either in the treatment head or in the column of air.

The overall results for surface dose at build-up region obtained via detector used in this study indicate that uncertainty exists in estimating the surface dose at a depth of 0.5 mm in build-up region. The use of Markus parallel plate ionization chamber with relatively large electrode separation may introduce uncertainties due to volume averaging and the fluence perturbation; thus, they are not suitable for measurements in non-equilibrium regions. Later, Gerbi and Khan[14] study for build-up dose using Markus parallel plate chamber and proposed a mathematical formula considering with the design of various parallel plate chambers, which has been used extensively by several authors[15,16] in their studies for build-up region measurements. Ideally, the surface doses should measure with extrapolation chambers in which distance of plate separation is varying. Their sensitive volume could be changed, and their response to the build-up region measurement was to be very good.

Alternatively, plane parallel ionization chambers instead of extrapolation chambers can be used for surface dose measurements by applying correction factors.

5.Conclusion

The percent depth doses at surface region are associated with the complex behavior because of steep dose gradient in build-up region and they depend on various factors such as field size, beam energy, SSD, beam modifying devices and on obliquely beam angles. In present study the surface dose behavior investigated for different SSDs and oblique beam incidences in the range used in clinical applications. Therefore, further research is required to study the surface dose. The surface dose for all beam energies has a modestly higher effect in the build-up region for different beam angles. The surface dose increases with increasing oblique beam angles. The dependence of beam angles is less significant in lower beam angles compared to highly obliquely angles. However, the difference is not substantial and clinically significant in highly oblique beam angles. It was found that as the SSD increases surface dose is decreases and this effect is significant for higher energies and vice versa. Knowledge of the dosimetric characteristics of the surface dose delivered by 6 MV, 10 MV and 15 MV at different SSDs and different beam angles are useful for implementations of IMRT, SRS, and SBRT techniques.

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Table 1: Relative surface doses defined at depth of 0.5 mm (IEC 60601) for different beam energies and SSDs

Beam energy	Source to surface distance (SSD)	Measured surface dose
6 MV	80 cm	25.96%
	90 cm	24.33%
	100 cm	22.94%
	110 cm	22.47%
	120 cm	21.89%
10 MV	80 cm	21.12%
	90 cm	18.39%
	100 cm	16.55%
	110 cm	15.41%
	120 cm	14.52%
15 MV	80 cm	22.07%
	90 cm	18.63%
	100 cm	16.25%
	110 cm	14.84%
	120 cm	13.71%

Table 2: Relative surface doses defined at depth of 0.5 mm (IEC 60601) for different beam energies and different oblique beam angles

Beam energy	Beam angles	Measured surface dose
6 MV	0°	22.94%
	20°	24.60%
	40°	30.42%
	60°	43.87%
	80°	74.89%
10 MV	0°	16.55%
	20°	17.91%
	40°	22.46%
	60°	36.63%
	80°	74.41%
15 MV	0°	16.25%
	20°	17.55%
	40°	20.62%
	60°	35.61%
	80°	75.01%

Figure 1: Phantom setup for a) normal beam incidence; b) oblique beam incidence to measure surface dose

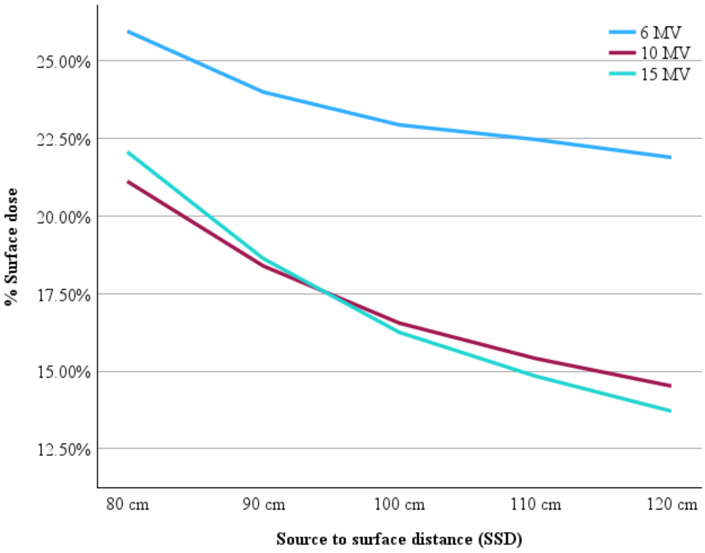

Figure 2: Variation of surface dose as a function of SSDs.

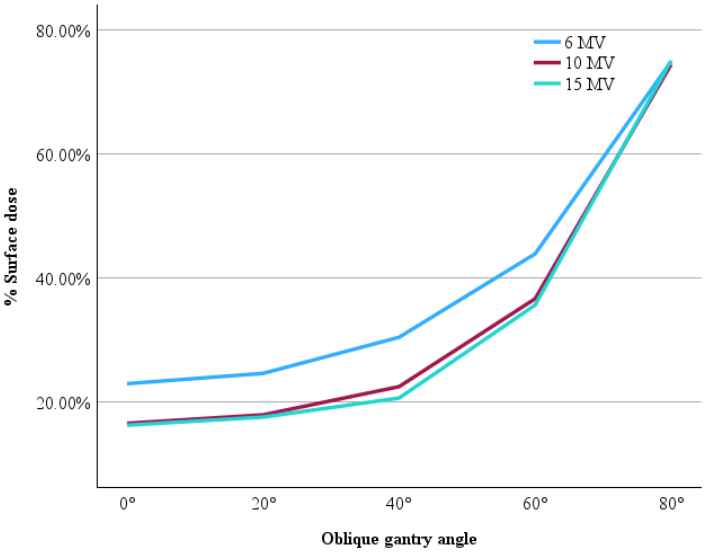

Figure 3: Variation of surface dose as a function of oblique beam angles