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ORIGINAL ARTICLE

Effects of immobilization beds on the dose in the entrance and exit dose region for Co-60, 4, 6 and 15 MV photons

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Summary

Purpose: *The aim of this study was to determine the effects of Styrofoam beds used for immobilization on build-up and exit dose regions for high energy photon beams.*

Materials and methods: *Build-up dose and exit dose measurements in central axis of Co-60 and 4, 6 and 15 MV photons at various field sizes and source to phantom distances were made in a water equivalent solid phantom with 2, 5 and 10 cm thick uniform Styrofoam beds at the surface. A Markus type plane-parallel ion chamber with fixed separation between collecting electrodes was used to measure the percent depth doses.*

Results: *The surface dose increased almost linearly with field size for Co-60, 4, 6 and 15 MV X-ray beams. The effect of immobilization (Styrofoam beds) on the surface dose increased with the thickness and this effect was lower with higher energies. When a 2 cm thick Styrofoam bed was used for immobilization, the surface dose in a 10×10 cm field was higher (43.9, 36.8, 28.8 and 14.9% for Co-60, 4, 6 and 15 MV, respectively).*

Conclusion: *As the Styrofoam bed was thicker, the maximum dose point moved closer to the surface of the phantom for all energies. The exit surface dose was also enhanced with the presence of Styrofoam beds and similar to the effects on the surface dose. This enhancement was the maximum 5% for high energy photon beams and 6% for Co-60 beam. The introduction of Styrofoam beds in the radiation beam for the immobilization of the patient increases surface and exit doses to a considerable extent.*

Key words: build-up dose, exit dose, immobilization device, radiotherapy, surface dose

Introduction

The introduction of high energy photon beams in radiotherapy has resulted in more inhomogeneous dose in the surface region. Lack of electronic equilibrium at the surface is known as the skin-sparing effect in megavoltage photon beams. The magnitude of this effect depends on several clinical setup parameters [1-5]. However, immobilization devices, such as Styrofoam beds, covering large parts of radiotherapy fields would modify the radiation dose to the skin by changing the build-up and exit doses. Thus, we have to know how our planning would be changed by the immobilization devices we use during the treatment, not only in terms of skin-sparing but also in terms of changing target volume localizations. Most radiation therapy treatment planning systems require look-up tables to calculate the patient dose distributions. Data are generally acquired in the form of the percent depth dose and beam profiles of the fields. Measurements are generally made in a water tank and using cylindrical chamber or diode. It is not possible to measure surface dose correctly using cylindrical chamber because of its volume. Various techniques are used to measure dose in the build-up region of high energy photon beams. Surface dose is accurately obtained using extrapolation chamber

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[6-8]. Also the fixed parallel plate chambers are used to measure surface dose using Gerbi's correction factors. Gerbi's correction factors for over-response were intended to be applied to all types of fixed parallel plate chambers [9-11]. These factors are specific to each chamber design and dependent on guard size, plate separation and volume.

Immobilization devices are used widely to reproduce patient positioning in radiotherapy. It is imperative to describe the effect of immobilization devices (Styrofoam beds, treatment tables, etc.)

The aim of this study was to determine the effects of Styrofoam beds used for immobilization in entrance (build-up) and exit dose regions for Co-60, 4, 6 and 15 MV high energy photons using a plane-parallel ion chamber with fixed separation between collecting electrodes. Data collected has been used in clinics to make the necessary dose corrections in patients treated with radiotherapy for which Styrofoam beds were used for immobilization.

Materials and methods

The effect of Styrofoam beds on the build-up, surface and exit dose was investigated to determine the effect of this material.

Co-60, 4 MV, 6 MV and 15 MV high energy photon beam measurements were performed with a parallel-plate ionization chamber (PTW-Markus 23343). The plate separation was 2 mm, and sidewall to collector distance 0.35 mm. For each measurement point, the relative ionization was acquired by dividing the charge collected at depth via a Keithley electrometer (Keithley Inc., Cleveland, OH, USA), by the charge at the depth of build-up and exit region. All ionization readings were corrected by first accounting for bias effects. These corrections were applied to all readings. Bias correcting was calculated with the formula below:

Bias correction [10-12]: $Q_{avg} = (Q_{+} + Q) / 2$

where,

Q_{avg}: average charge used for relative ionization

Q_{+}: charge accumulated with positive bias

Q_{-}: charge accumulated with negative bias

The measured percent depth dose was corrected for the chamber characteristic according to the Gerbi method [10-13]:

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

where,

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

$\xi(0,E)$ = energy dependent chamber factor

$\xi(0,E)$ = 8.01 for Co-60 beam, 6.57 for 4 MV beam, 5.07 for 6 MV beam, and 2.37 for 15 MV beam

IR = ionization ratio [14] (Co – 60 = 0.579, 4MV= 0.626, 6MV=0.675, 15MV= 0.763)

P′ = corrected percent depth dose

P = measured relative depth ionization

E = energy

C = sidewall-collector distance (0.35 for PTW Markus 23343)

l = plate separation (2 mm for PTW-Markus 23343)

α = constant of 5.5

d = depth of measurements from surface to d max

All build-up dose measurements were made for fixed SSD (source-to-skin distance) geometry as shown in Figure 1. 40×40 cm solid water phantom was used for the measurements on Co-60, 4, 6 and 15 MV photon beams with 5×5, 10×10 and 25×25 cm field sizes and different depths in the build-up region from open field. The Styrofoam beds with a density of ρ=0.044 g/cm^3 and 2, 5 and 10 cm thickness were placed on the phantom surface.

The exit dose measurements were made through the back of the chamber where the lower plate was proximal as shown in Figure 2. Measurements were taken through 16 cm of water equivalent solid phantom at the exit surface while varying the thickness of Styrofoam beds as a backscatter material placed behind the surface. Build-up dose measurements were carried out using SSD's ranging from 80 to 140. Exit dose measurements were made at 100 cm SSD. Fixed times were used for Co-60 beam and 100 monitor units (MU) were used for high energy photon beam.

Results

Surface and build-up dose characteristics

Percent depth doses in the build-up region at 100 cm SSD with 2, 5 and 10 cm thick Styrofoam beds are presented in Figure 3 a-d. Each curve set contained an open beam build-up curve for comparison. Depth dose values were plotted as percent of charge collected at a depth corresponding to the nominal dmax for Co-60, 4, 6 and 15 MV x-ray beams (0.5, 1, 1.5 and 3 cm, respectively). The surface dose varied with the thickness of Styrofoam bed used for immobilization.

The surface dose from a 10×10 cm for Co-60 with open beam, 2, 5 and 10 cm Styrofoam were 24.3, 68.2, 79.1 and 92.4%; for 4MV 17.4, 54.2, 67.2 and 77.3%; for 6 MV 12.6, 41.4, 52.2 and 67.7%; and for 15 MV 10.2, 25.1, 38.3 and 51.2%, respectively. The surface dose increased with increasing thickness of Styrofoam beds. The maximum dose point moved closer to the surface.

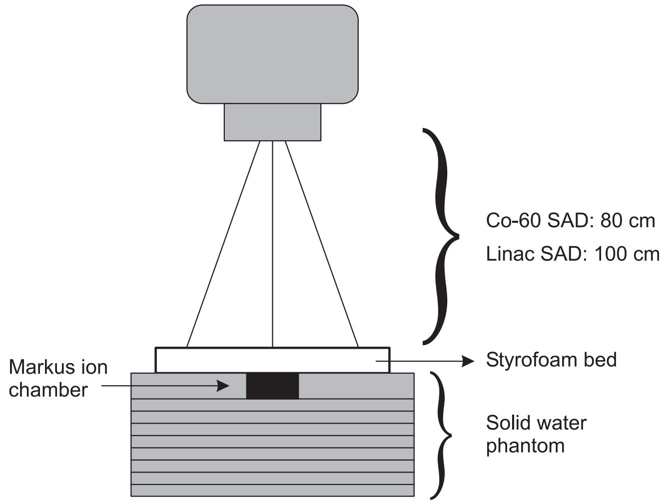

Figure 1. Experimental set-up for surface and build-up dose. SAD: source-axis distance.

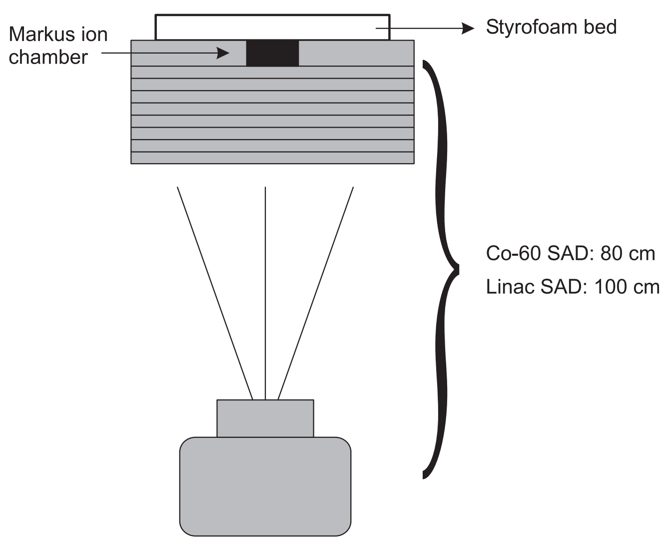

Figure 2. Experimental set-up for exit dose. SAD: source-axis distance.

As shown in Table 1, the surface dose increased almost linearly with field size for Co-60, 4, 6 and 15 MV x-ray beams.

Dependence on SSD

The surface dose decreased for Co-60, 4, 6 and 15 MV with increasing SSD from a 10×10 cm open field. Figure 4 summarizes these results. Similarly, surface dose decreased for all energies with increasing SSD with 2, 5 and 10 cm Styrofoam covering surface. Figure 5 shows the surface dose for 15 MV x-rays.

Exit dose characteristics

The exit dose was enhanced with the presence of Styrofoam beds; in comparison with an open field the maximum was 5% for high energy photons and 6% for Co-60.

Discussion

Any material or device introduced between a radiation source and the patient may change the dose at

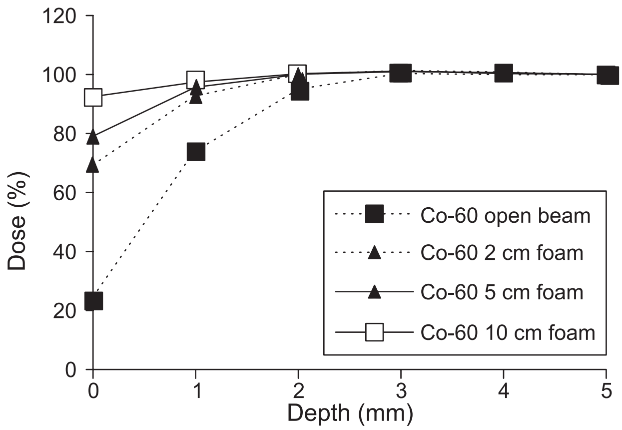

Figure 3a. Comparison of build-up curves for a 10×10 cm, 80 cm source-skin distance, Co- 60 beam with and without uniform thickness Styrofoam beds.

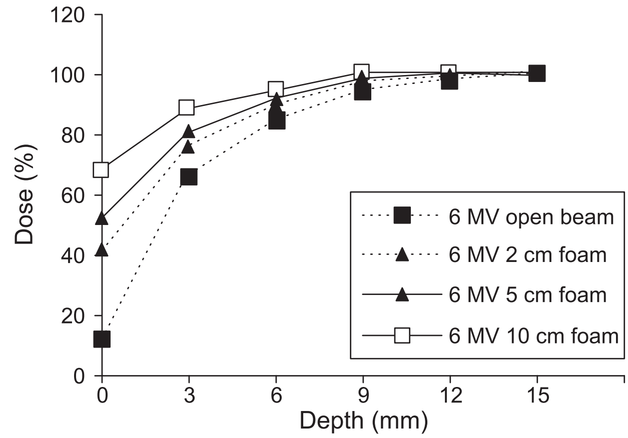

Figure 3c. Comparison of build-up curves for a 10×10 cm, 100 cm source-skin distance, 6 MV x-ray beam with and without uniform thickness Styrofoam beds.

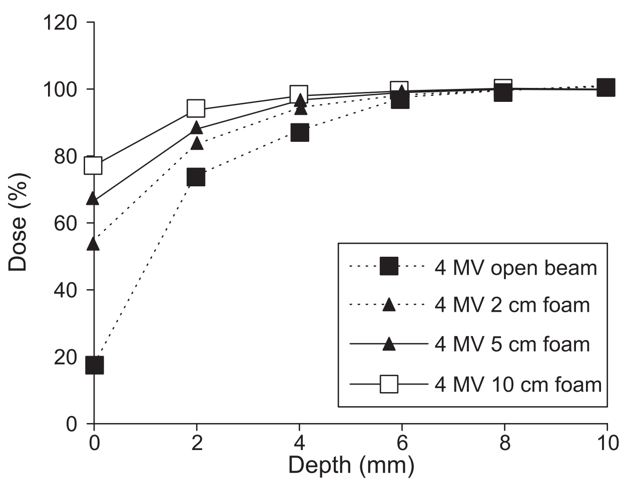

Figure 3b. Comparison of build-up curves for a 10×10 cm, 100 cm source-skin distance, 4 MV x-ray beam with and without uniform thickness Styrofoam beds.

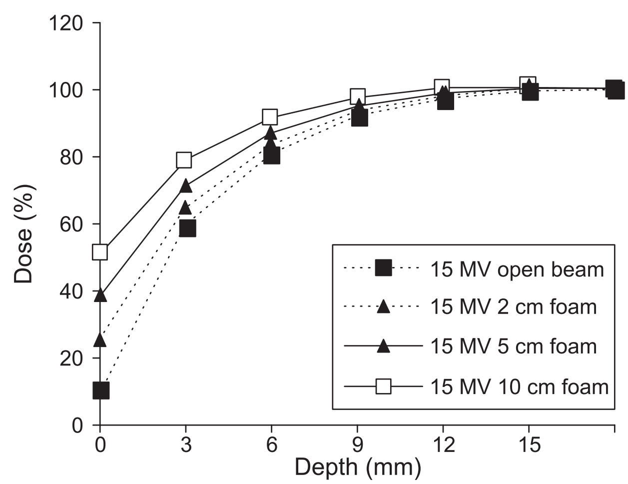

Figure 3d. Comparison of build-up curves for a 10×10 cm, 100 cm source-skin distance, 15 MV x-ray beam with and without uniform thickness Styrofoam beds.

Table 1. Measured percentage surface dose behind styrofoam beds

Field size	*Co-60 surface dose %*	*4MV surface dose %*	*6 MV surface dose %*	*15 MV surface dose %*
5×5 cm, open field	15.7	11.0	8.0	5.0
5×5 cm, 2 cm foam	64.0	49.3	37.7	19.4
5×5 cm, 5 cm foam	69.4	60.6	47.9	31.6
5×5 cm, 10 cm foam	75.0	67.0	55.4	40.4
10×10 cm, open field	24.3	17.4	12.6	10.2
10×10 cm, 2 cm foam	68.2	54.2	41.4	25.1
10×10 cm, 5 cm foam	78.0	67.2	52.2	38.3
10×10 cm, 10 cm foam	79.0	77.3	67.7	51.2
25×25 cm, open field	54.0	35.9	27.8	29.1
25×25 cm, 2 cm foam	80.5	63.6	53.6	43.1
25×25 cm, 5 cm foam	81.0	73.6	65.1	56.2
25×25 cm, 10 cm foam	82.0	82.2	77.1	68.5

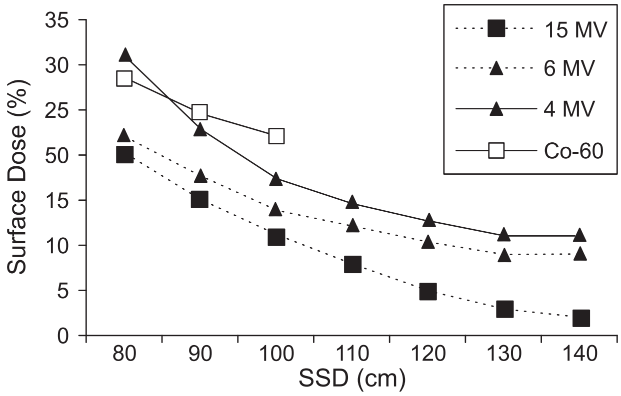

Figure 4. Surface dose as a function of energy and source-skin distance (SSD) with field size of 10×10 cm without Styrofoam beds.

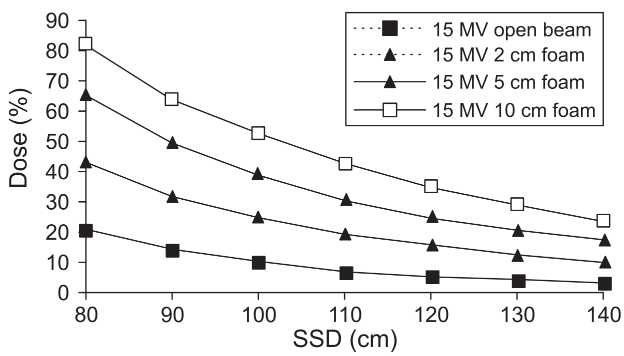

Figure 5. Surface doses as a function of source-skin distance (SSD) with field size of 10×10 cm for 15MV x-ray beam with and without uniform thickness Styrofoam beds.

surface and buildup region. If surface dose is increased substantially, the skin may become a dose limiting structure, despite the use of high energy radiation. Patient fixation with materials like Styrofoam beds are used widely to reproduce patient positioning in radiotherapy [15]. The effect of Styrofoam on the entrance and exit doses on the skin should be known. Having definitive dosimetry at the surface and buildup region is important to optimize bolus thickness required to enhance surface dose in clinical cases such as breast cancer [16-19].

Mellenberg discussed the effect of various materials introduced into photon beams [20]. He reported that polyurethane foams (ρ=0.028 g/cm^3) of 2.5 and 10 cm thickness would increase the surface dose for a 10×10 cm field by 36.3, 52.2 and 62.7% for 6 MV and 23.7, 35.6 and 46.6% for 15 MV, with increasing thickness. We found similar surface dose increases with 15 MV and even higher dose increases for 6 MV photons with Styrofoam beds (ρ=0.044 g/cm^3) used for patient immobilization. Johnson et al. used Vax/Fix (ρ=0.03 g/cm^3) for immobilization with surface doses of 81 and 98.3% for 2.1 and 5.6 cm foam thicknesses, respectively, for C0-60 beams, and 50.8 and 68.4% for 6 MV photons [16]. Even though the density (ρ=0.044 g/cm^3) of Styrofoam we used was higher than the density of Vax/Fix (ρ=0.03 g/cm^3) used by Johnson et al., we found lower surface doses for both Co-60 and 6 MV photons with 2 and 5 cm thick Styrofoam beds (68 and 79% for Co-60; 41 and 52% for 6 MV). The 0.15 mm thick bag used to hold the Vax can be the reason of higher surface doses with Vax/Fix system compared with Styrofoam beds for immobilization.

The results of this study, as shown in Table 1, have been used in radiotherapy practice in our department to make the necessary dose corrections in our dosimetry where Styrofoam beds have been used for patient immobilization. The immobilization devices could also affect the dose distribution at the target volumes. This could be a source of systematic error in radiotherapy planning if not known and corrected for.

An immobilization device in the radiation beam should be considered for all these aspects in dosimetry. Higher energy and thinner Styrofoam bed spare the skin better. However, even with high energies (e.g. 15 MV) and thin Styrofoam beds (e.g. 2 cm thick) special consideration should be given. For example, surface doses for a 10×10 cm field size and 2 cm thick Styrofoam compared with an open beam are higher (43.9, 36.8, 28.8 and 14.9% for Co-60, 4, 6 and 15 MV, respectively). This can be 68.1, 59.9, 55.1 and 41% with 10 cm thick Styrofoam for Co-60, 4, 6 and 15 MV, resulting in considerable probability for high grade skin reaction and errors in target determination with decreased tumor control.

We also found considerable enhancement in exit surface doses with the presence of Styrofoam beds in the radiation beam. Exit dose increased by 5% for high energy photon beams and by 6% for Co-60 using Styrofoam beds compared with open beams.

In conclusion, the use of Styrofoam beds in the beam for patient immobilization increases the surface and exit dose to a considerable extent. Immobilization devices used in radiotherapy practice must also be investigated for their effects on dose distribution in the target volumes.

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