Turk J Med Sci
32 (2002) 211-215
© TÜBİTAK

Nadir KÜÇÜK[1]
Ayhan KILIÇ[1]
Gönül KEMİKLER[2]
Lütfi ÖZKAN[1]
Kayıhan ENGİN[1]

Analyses of Surface Dose from High Energy Photon Beams for Different Clinical Setup Parameters

Received: October 08, 2001

[1]Department of Radiation Oncology, Uludağ University Medical College, Bursa,
[2]İ.Ü.Oncology Institute, Radiation Oncology, İstanbul - Turkey

Abstract: Surface and build-up region doses of 6, 15 and 25 MV photon beams were investigated for several clinical setup parameters. Evaluated setups included open fields, physical wedge (PW) fields, virtual wedge (VW) fields and blocked fields. The effects of field size, acrylic block tray, source-to-surface distance (SSD) and off-axis distance on surface dose were determined for each of these setups. Siemens Mevatron MD2 (6-15 MV) and Mevatron-KD2 (6-25 MV) linear accelerators were used to measure both the surface and build-up region doses. The surface dose increased as field size increased in open fields. There was no significant difference between 6 MV photon beam surface dose values for both machines. The surface dose for PW fields was lower than the dose for an open field, but higher in the case of large fields and higher degree wedges. The VW field surface doses were higher than the dose for PW and quite similar to the open fields. With the use of an acrylic block tray, the surface dose increased for all field sizes, but the increase was dominant for large fields. The surface dose for blocked fields was lower than the dose for open fields. As SSD decreased, the surface dose increased, and this effect was dominant, especially in larger field sizes with an acrylic block tray.

Key Words: skin dose, wedge, blocked field

Introduction

X-ray and γ-ray beams used in radiotherapy are contaminated with secondary electrons. Skin dose has two components depending on secondary electrons produced from photon interactions with air, collimator jaws, the patient surface and any other scattering material. These components are (i) secondary electrons generated in the patient (1,2) and (ii) contaminant electrons from the treatment head (1).

Nizin (2) reported two steps for photon interactions, namely primary interaction and multiple scattering within the medium. There are two sources for contamination: (i) treatment head materials (collimator jaws, flattening filter, beam monitor chambers and the target) (3,4) and (ii) treatment setup parameters (field size, wedge, tray, block and SSD) (5-7). The amount of these contamination electrons affect the surface dose (3). It is not possible to change the effect of treatment head materials on skin dose in clinical applications, but skin dose can be changed by using different treatment setup parameters. Therefore, the knowledge of how parameters affect the skin dose at the skin surface are essential for proper treatment.

The skin consists of three layers: the epidermis, the dermis and the subcutaneous fatty tissue (8). The thickness of the epidermis and dermis is 0.05-0.15 mm and 1-2 mm in most locations, respectively. The subcutaneous fatty tissues lie under the dermis. It is important to know the dose distribution of these layers before treatment because of possible biological complications of high skin doses in radiotherapy treatment, such as desquamation, erythema, fibrosis, necrosis and epilation.

The purpose of this study was to investigate surface doses of different clinical setup parameters including field size, PW, VW, acrylic block tray, SSD and blocked field for high energy photon beams.

Materials and Methods

Surface dose measurements were carried out using a Markus parallel-plate ion chamber (PTW, Freiburg, Germany) in a plastic water phantom (Nuclear Associates, Victoreen) for various setup parameters. The measurements were performed using Siemens Mevatron-MD2 (6 MV, 15 MV) and Siemens Mevatron-KD2 (6 MV, 25 MV) linear accelerators. For the normalization depth, i.e., the depth of maximum dose, 1.5, 3 and 3.5 cm were chosen for 6, 15 and 25 MV photon beams, respectively.

Central axis depth dose measurements were made in a plastic water phantom. The Markus-type chamber was imbedded in a plastic water phantom and 15 cm of backscatter thickness was used to ensure phantom scatter equilibrium. Epoxy-based material, 1.12 g/cm^3 density, plastic water phantom sheets of 1 mm thickness were placed, one by one, on the chamber. A SSD of 100 cm was chosen for measurements. A polarizing potential of 300 V was reversed for all measurements because of a large polarity effect observed at the phantom air interface (9). The percentage build-up region depth dose data (ranging from 0 to 5 cm depth) were measured for each setup. Readings at the phontom surface (depth = 0) were normalized to readings at the maximum depth to obtain relative skin doses for all energies.

Measurements of skin doses were performed at 100 cm SSD with different sizes of open fields ranging from 5 x 5 to 40 x 40 cm^2. Then the changes in skin dose were studied with wedges, acrylic block tray and blocks. Skin dose values were obtained for 15º, 30º, 45º and 60º PW and VW filters and compared with each other. VW measurements were made on a Mevatron-KD2 machine, because only the Mevatron KD2 has a VW system. Six millimetre thicknesses of acrylic block tray were placed on the beam to determine its effect on the skin dose. The tray was used to support the cerrobend blocks and it was placed at the accessory tray holder 56.5 cm from the source. Twenty-five percent of the field was blocked with cerrobend and the effect of custom blocks on skin dose was measured for 5 x 5, 10 x 10, 15 x 15 and 20 x 20 cm^2 field sizes. The cerrobend blocks were placed above the tray. The effect of SSD was studied with different beam modifiers. Three different SSDs were chosen for measurement (85, 100 and 120 cm). Finally, the skin dose at off-axis distance in a field was investigated for a 20 x 20 cm^2 field size for different energy. Off-axis distance was 3, 6 and 9 cm from the central axis.

The Markus parallel-plate chamber overrespondes in the build-up region, especially at the surface, because of the large separation and small guard ring. Correction factors were used to find real absorbed dose values for this chamber, based on the results of extrapolation chamber measurement (10,11). The relative ionization values were corrected to zero-chamber volume relative absorbed dose values by using Gerbi and Khan's (10) reported data for 6, 18 and 24 MV photon beams for different commercially available plane-parallel ionization chambers. Gerbi and Khan's correction factors (10.6%, 4.3% and 2.4% for 6, 15 and 25 MV, respectively) were used in our study.

Measurements and Results

Figure 1 shows the surface dose values for open fields. Skin dose increased as field size increased. The skin dose values measured from two different linear accelerators were almost the same for 6 MV. Although the skin dose values of 6 MV were approximately the same as those of 15 MV but higher than those of 15 MV for the field lower than 20 x 20 cm^2. This can be seen clearly in Figure 3. Measured skin dose values for 6 MV and 15 MV were lower than those of 25 MV except with smaller field sizes (≤10 x 10 cm^2).

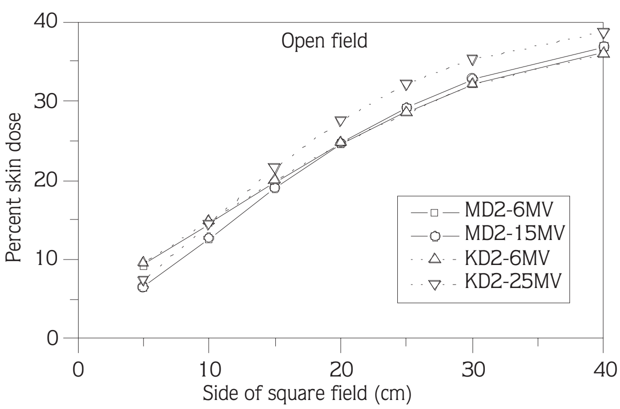

Figure 1. A comparison of skin doses for open fields for different energy and field sizes.

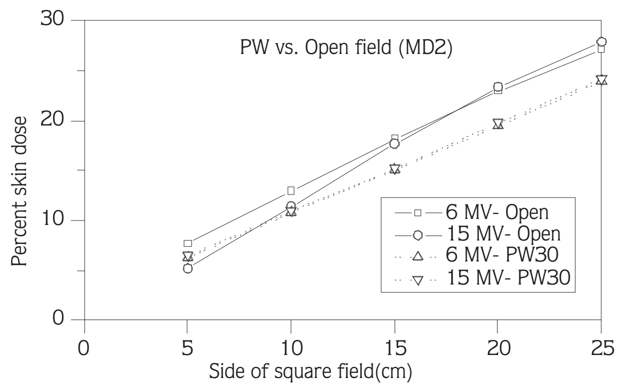

Figure 2. A comparison of skin doses 30º PW vs. open fields for MD2.

The results of our skin dose measurement for PW are presented in Figures 2-3 for MD2 and KD2 machines, respectively. The skin dose values of the same energy and wedge angle for different machines were similar. The skin dose for a wedge field increased as field size increased but skin dose value for PW fields lower than as compared with for the same open fields. PW eliminates secondary electrons but generates new electrons. It may be concluded that the number of electrons produced by the wedge was lower than the number of electrons eliminated by the wedge. The skin dose values of 6 MV were higher than those of 15 MV for smaller wedge angles (15º and 30º) but nearly the same for 45º and 60º wedge angles. Measured skin doses for 25 MV were higher than those for other energies for all wedge angles and large field sizes.

The VW skin dose values were very similar to those of open fields. This similarity is given in Figure 4. A comparison of skin dose values for PW and VW are given in Figure 5 for 30º wedge angle. PW skin dose values were lower than VW skin dose values.

Readings were taken for the entire range of field sizes available on the linear accelerators (5 x 5 cm^2 to 40 x 40 cm^2) with an acrylic blocking tray. Measured skin dose values were compared to those of open fields. Skin dose values with the acrylic block tray were higher than those with the open field (Figure 6). It may be concluded that the effects of the blocking tray on skin dose were quite significant and increased with increasing field size (especially in fields greater than 10 x 10 cm^2).

The skin dose differences caused by using 25% blocks in the field are given in Figure 7. The skin dose for blocked fields was lower than that for open fields. For example, the skin dose of a 20 x 20 cm^2 open field is higher than that of 20 x 20 cm^2 field blocked to a 10 x 10 cm^2 field size, because the irradiation field becomes smaller and scattering decreases.

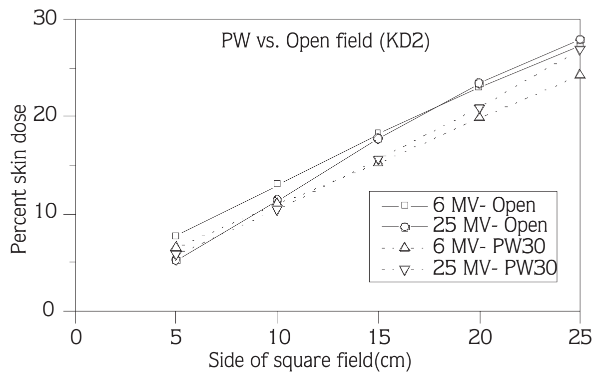

Figure 3. A comparison of skin doses 30º PW vs. open fields for KD2.

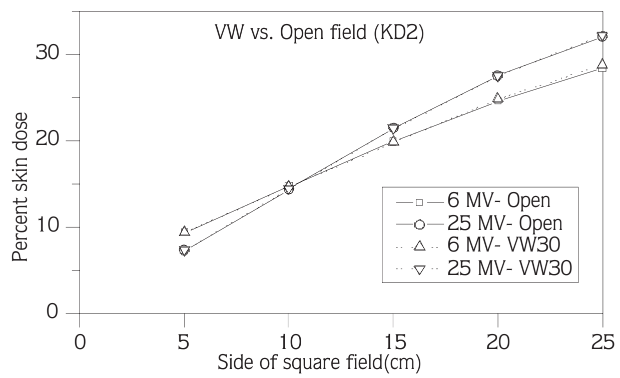

Figure 4. A comparison of skin doses 30º VW vs. open fields for KD2.

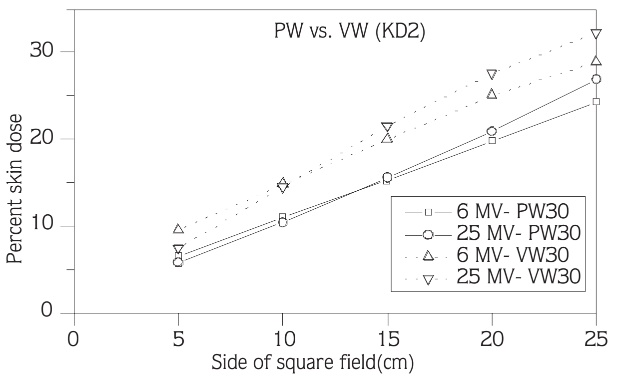

Figure 5. A comparison of skin doses 30º PW vs. VW fields for KD2.

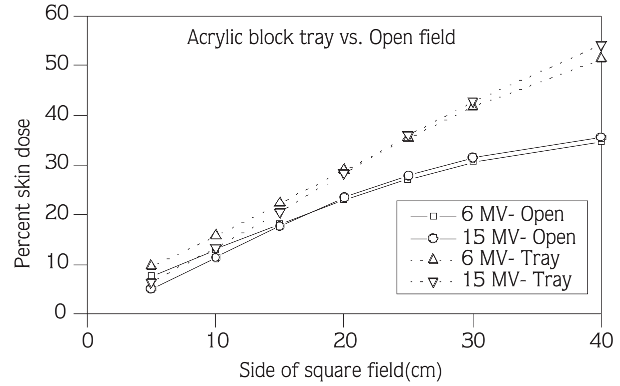

Figure 6. A comparison of skin doses for open field vs. acrylic block tray for MD2.

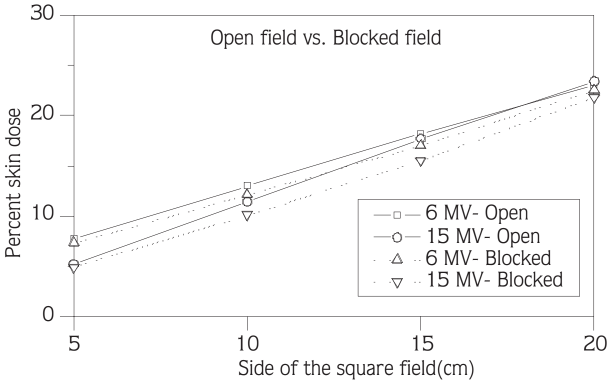

Figure 7. A comparison of skin doses for open vs. 25% blocked field for MD2.

Figure 8 shows the variation in skin dose with SSD. The skin dose increased as SSD decreased in larger field sizes.

The skin dose measurements at off-axis distance (3, 6 and 9 cm from the central axis) were made with a 20 x 20 cm^2 field size for open, 25% blocked and acrylic block tray fields. As can be seen in Figure 9, the skin dose decreased as the off-axis distances increased. This effect is dominant at the field edges and it is clear from this figure that the skin dose measured on the central axis is representive of the maximum skin dose in the field.

Discussion and Conclusions

High energy photon beams, which are used for treating deep-seated tumors, have a skin-sparing effect but secondary electrons generated in the patient or contaminanting electrons produced outside the patient, in air or structures in the accelerator head may reduce this effect (12).

The measurements were made with 6 MV, 15 MV and 25 MV photon beams using two linear accelerators from the same company. According to our results the surface dose values were similar for 6 MV photon beams for both accelerators because the treatment heads are similarly designed.

There is a strong relationship between field size and skin dose. As the field size increased, the skin dose increased. This increase is due to increased electron emission from the collimator and air.

The skin dose values for wedge fields increased as field size increased (Figures 3-5). The skin dose decreased as the wedge angle increased, except with a large wedge angle (60º) for small fields (<10 x 10 cm^2 field) for all photon beams. This effect is valid for all field sizes for a 6 MV photon beam. As wedge angle increased, skin dose increased for large field sizes (>20 x 20 cm^2 for 15 MV and >15 x 15 cm^2 for 25 MV). Kim et al. (1) reported that PW both eliminates electrons from upstream and generates electrons itself. They noted that the number of electrons produced in the wedge is less than the number of electrons eliminated by the wedge for smaller field sizes and smaller wedge angles. According to their report, this effect is reversed only with larger field sizes and larger wedge angles. Measured skin doses for PW (30º) were 10.8% and 9.3% for 6 MV and 15 MV, respectively for 10 x 10 cm^2 field size. These results agree with those in the literature. For example, the skin dose value measured by Kim et al. (1) was the same (9%) for 8 MV and 18 MV for 30º PW and 10 x 10 cm^2 field

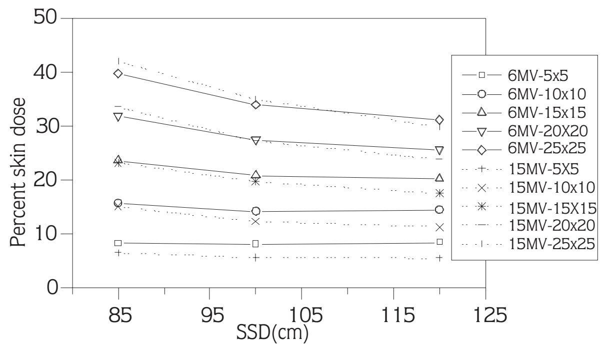

Figure 8. Effect of SSD on skin dose for different field sizes for MD2.

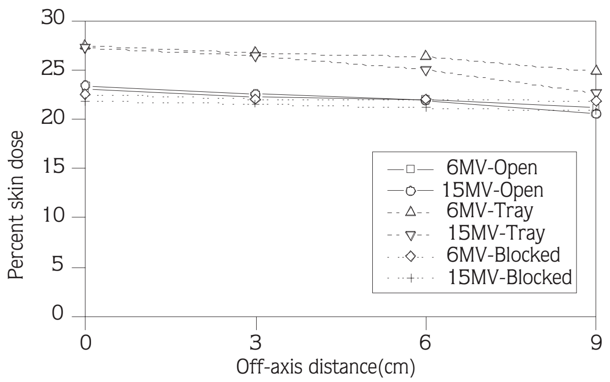

Figure 9. A comparison of skin dose at off-axis distance for 20 x 20 cm^2 field size.

size. According to Li et al. (5), the skin doses for 30º wedge field were 10.4% and 10.2% for 8 MV and 18 MV. The skin doses of VW were similar with open fields and PW skin dose values are lower than open field and VW skin dose values.

Skin dose values with the acrylic block tray were higher than those with an open field. This effect was dominant in larger field sizes. For example, Figure 8 shows similarity in surface dose with open field, in comparison with an acrylic block tray in place for 5 x 5 cm^2 field size, but the surface dose was changed from 35% to 50% by adding an acrylic block tray for 40x40 cm^2 for a 6 MV photon beam. For 6 MV, the surface dose increased in the presence of the acrylic block tray from 13% and 18.2% to 14.2% and 20.8% for 10 x 10 cm^2 and 15 x 15 cm^2 field sizes, respectively. Tannous et al. (13) found 16% and 24% skin dose values in the presence of an acrylic block tray for 10 x 10 cm^2 and 15 x 15 cm^2 field sizes, respectively, for a 6 MV beam, considerably higher than our values. The tray eliminates the electrons from upstream and generates new secondary electrons by itself (1). The number of electrons originating at the tray is larger than the number of electrons eliminated by the tray. Secondary electrons originating at the tray can penetrate the tray and reach the patient, because the acrylic block tray increased the skin dose more significantly.

The skin doses of a 20 x 20 cm^2 open field were 23% and 23.4% for 6 MV and 15 MV, respectively. The skin doses of a 20 x 20 cm^2 field blocked to a 10 x 10 cm^2 field were 16.7% and 15.5% for the same energies. In contrast, Mellenberg (6) measured 29.7% and 27.2% skin dose values for a 20 x 20 cm^2 open field for 6 MV and 15 MV, respectively. According to this study, the skin dose of a 20 x 20 cm^2 field blocked to a 10 x 10 cm^2 field was 17.8% and 15%. Mellenberg (6) noted that the build-up region for a 20 x 20 cm^2 field blocked to a 10 x 10 cm^2 field closely match depth doses for a 10 x 10 cm^2 field with a tray in place (15.1% and 12.9%).

The skin dose increased as SSD decreased. This effect was dominant in larger field sizes and high energies. The air between source and skin generates secondary electrons and these electrons absorbed or scattered in air depend on beam divergence and some of them can reach the patient's skin. As SSD increased, the number of electrons that reach the patient's skin decreased (12). This result agrees with those o f Kim et al. (1) (Figure 9).

Correspondence author:
Ayhan KILIÇ
University of Uludağ, Medical College,
MA Radiotherapy Center,
16059 Görükle
Bursa-TURKEY

References

1. Kim S, Liu CR, Zhu TC, Palta JR. Photon beam skin dose analyses for different clinical setups. Med Phys 25: 860-6, 1998.
2. Nizin PZ. Electronic equilibrium and primary dose in collimated photon beams. Med Phys 20: 1721-29, 1993.
3. Petti PL, Goodman MS, Sisterson JM, Biggs PJ, Gabriel TA, Mohan R. Sources of electron contamination for the Clinac-35 25-MV photon beam. Med Phys 10: 856-61, 1983.
4. Nilsson B, Brahme A. Electron contamination from photon beam collimators. Radiother Oncol 5: 235-44, 1986.
5. Li Z Klein EE. Surface and peripheral doses of dynamic and physical wedges. Int J Radiat Oncol Biol Phys 37: 921-25, 1997.
6. Mellenberg DE. Dose behind various immobilization and beam-modifying devices. Int J Radiat Oncol Biol Phys 32: 1193-97, 1995.
7. Shirish KJ, Pennington EC. Depth dose characteristics of 24-MV X-ray beams at extended SSD. Med Phys 18: 292-94, 1991.
8. Shimm DS, Cassady JR. The Skin. In: Cox JD, Moss Radiation Oncology 7th ed., Mosby 1994, pp: 99-118.
9. Gerbi BJ, Khan FM. The polarity effect for commercially available plane-parallel ionization chambers. Med Phys 14: 210-15, 1987.
10. Gerbi BJ, Khan FM. Measurement of dose in the build-up region using fixed-separation plane-parallel ionization chambers. Med Phys 17: 17-26, 1990.
11. Mellenberg DE. Determination of build-up region over-response corrections for a Markus-type chamber. Med Phys 17: 1041-44, 1990.
12. Khan FM. The physics of radiation therapy, Williams and Wilkins, Baltimore,1994, pp: 323-32.
13. Tannous NBJ, Gagnon WF, Almond PR. Build-up region and skin dose measurements for the Therac 6 linear accelerator for radiation therapy. Med Phys 8: 378-81, 1981.