Original Article

Variation of beam characteristics between three different wedges from a dual-energy accelerator

C. Varatharaj, M. Ravikumar, S. Sathiyan, Sanjay. S. Supe

Department of Radiation Physics, Kidwai Memorial Institute of Oncology, Hosur Road, Bangalore, India

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ABSTRACT

The use of megavoltage X-ray sources of radiation, with their skin-sparing qualities in radiation therapy, has been proved useful in relieving patient discomfort and allowing higher tumor doses to be given with fewer restrictions due to radiation effects in the skin. The purpose of this study was to compare the dosimetric characteristics of a physical and enhanced dynamic wedge from a dual-energy (6 and 18 MV) linear accelerator such as surfaces doses with different source to surface distances (SSD), half value layer (HVL) in water and peripheral doses for both available energies. At short SSD such as 85 cm, higher surface doses are produced by the lower wedges by the short wedge-to-skin distance. For physical wedged field, at heel edge side HVL value was high (17 cm) compared with the measured that of EDW (15.1 cm). It was noticed that, the HVL variation across the beam was significantly higher for 6 MV X-rays than for 18 MV X-rays. The lower wedge has the maximum variation of peripheral dose compared to other wedges. The three wedge systems discussed in this work possess vastly different dosimetric characteristics. These differences will have a direct impact on the choice of the wedge system to be used for a particular treatment. Complete knowledge of the dosimetric characterisitics, including the surface and peripheral doses, is crucial in proper choice of particular wedge systems in clinical use.

Key words: Enhanced dynamic wedge, half value layer in water, phyical wedge, surface dose

Introduction

The use of megavoltage X-ray sources of radiation, with their skin-sparing qualities in radiation therapy, has been proved as useful in relieving patient discomfort and allowing higher tumor doses to be given with fewer restrictions due to radiation effects in the skin. However, high doses now given for deep tumors may require careful consideration of dose distributions in the buildup region in order to avoid irreparable damage to the skin and subcutaneous tissues. Wedge-shaped isodoses are necessitated by common clinical situations, such as sloped patient surfaces, regions of intersecting beams, and irregularly shaped tumor volumes. The wedge-shaped isodoses have been achieved by many methods. Generally physical wedges (made of metals) are included when accelerators are shipped as standard accessories. The physical wedge can provide wedge angles of 15°, 30°, 45°, 60° only for symmetric field size up to 20 cm width. Physical wedges have a number of adverse practical and dosimetric attributes. They are limited in size, are heavy, usually must be lifted overhead, and block the light field. In addition, the high-density, high-atomic number (Z) materials create additional low-energy electron and photon scatter, which increases both peripheral and surface dose.[1,2]

Peripheral dose (PD), or the dose outside the geometrical boundaries of the radiation field, is of clinical importance when anatomical structures with low dose tolerances might be involved.[3] Peripheral dose received by radiosensitive structures, such as eye lens, contralateral breast, thyroid gland, ovaries, testes, and fetus, located outside the boundaries of the primary radiation field is of clinical interest and may lead to secondary healthy issues.[4,5] The scattered dose to testes from treatment of seminoma and pelvic tumors may be associated with an impairment of spermatogenesis. Pelvic irradiation after lateral ovarian transposition out of the irradiated area can cause early

Address for correspondence:
Dr. M. Ravikumar
Department of Radiation Physics,
Kidwai Memorial Institute of Oncology,
Hosur Road, Bangalore-560 029, Karnataka, India.
E-mail: drravikumarm@gmail.com

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menopause.[6] Gonadal exposure from radiotherapy in the abdominopelvic region can result in an increased incidence for development of hereditary disorders in offspring of adult and pediatric cancer patients.[7]

The American Association of Physicists in Medicine Task Group 36 [AAPM TG-36] data[8] can be used to estimate peripheral dose distributions for various treatments and to determine the need for additional shielding. However, the report data were not obtained on linear accelerators with different type of wedges.

The enhanced dynamic wedge (EDW) is an option on Varian LINACs (Varian Medical Systems, Palo Alto, CA). It provides seven wedge angles (10°, 15°, 20°, 25, 30°, 45, and 60° for both symmetric and asymmetric field sizes up to 30 cm width). In this mode of treatment, the sloping dose distributions generated by one of the upper jaws sweeps across the field from its maximum open position to within 0.5 cm of the opposite jaw, creating a wedged beam profile. In order to deliver a dynamically wedged field, the length of the treatment field is divided into 20 segments, and the speed of the moving jaw and the dose rate within each segment are controlled based on a calculated segmented treatment table (STT) generated by the LINAC computer. The STT is essentially a table of positions of the moving jaw versus the cumulative monitor units delivered at each position. The STT for a particular wedged delivery is a product of weighted averaging between an open-field STT and a 60° golden STT. The details of STT generation and delivery have been explained by Varian.[9] The advantages of EDW over the conventional physical wedges are: they eliminate the physical wedges; they can generate any arbitrary wedge angle; they reduce the treatment time; they reduce a dose that is outside the treatment plan and they provide better dose distributions of a straight isodose line without beam hardening.

In our linear accelerator equipped with three type of wedges, i.e. enhanced dynamic wedges, upper physical wedges mounted above the blocking tray and lower physical wedges mounted below the blocking tray. Due to their different physical constructions as well as their relative positions to the linear accelerator source, these wedge systems posses markedly different dosimetric characteristics.[10] While there have been a number of studies on the surface doses produced in X-ray beams, with or without beam modifying devices including physical wedges and dynamic wedges,[11] the simultaneous availability of all three wedge systems on a single linear accelerator allows a direct comparision of their dosimetric properties. In general all published datas [12-14] were compared for the physical wedges with motorized or dynamic wedges in termes mainly with TPS required data such as wedge factor, profile measurement, isodose comparisions, etc. In the present study, we have compared some more dosimetric characteristics of a physical and enhanced dynamic wedges from a dual-energy (6 and 18 MV) linear accelerator such as surfaces doses with different source to surface distances (SSD), HVL in water, and peripheral doses for both available energies.

Materials and Methods

This study used the Varian Clinac-DHX linear accelerator which is equipped with three different type of wedges. The surface dose with physical and enhanced dynamic wedges were measured using a parallel plate chamber at 85 and 100 cm source to surface distance (SSD), for 6 and 18 MV photons. The field size was maintanined as 10×10 cm^2 and 20×20 cm^2 for 15^o, 30^o and 45^o wedges, and 10×10 cm^2 and 15×15 cm^2 for 60^o wedges.

To compare the change in beam quality with physical and enhanced dynamic wedge, half value layer (HVL) was measured[15] using a a calibrated small cylindrical air ionization chamber (RK Chamber, Scanditronix Wellhofer, Uppsala, Sweden) with an active volume of 0.12 cm^3 and connected to the calibrated electrometer (RDM-1F, Therados, Uppsala, Sweden). The chamber has been covered with brass build up cap positioned at 2 m distance from the source, and the distance from the target to absorber distance was maintained as 1 m. Transmission measurements were made for varying thickness of the white polystyrene phantom placed on the couch. The couch was rotated through 90^o to obtain longer measurement distances and scatter-free measuring conditions.

Peripheral dose measurement[16] was carried out by a radiation field analyser (RFA-300, Scanditronix Wellhofer, Uppsala, Sweden) having the scanning area dimensions of $495 \times 495 \times 495$ mm^3 (X / Y / Z). The positional reproducibility of RFA-300 is $\pm$ 0.1 mm and the positional accuracy is $\pm$ 0.5 mm. Ionization was collected by a calibrated small cylindrical air ionization chamber (RK Chamber, Scanditronix Wellhofer, Uppsala, Sweden) with an active volume of 0.12 cm^3 and connected to the calibrated electrometer (RDM-1F, Therados, Uppsala, Sweden). Data were taken from 3 to 24 cm away from the field edge. In general, Published data show that the depth dependence of PD distribution is small.[17,18] Therefore, measurements were made only at the dose maximum depth at 1.5 cm for 6 MV and 3.3 cm for 18 MV photons for the linear accelerator, whereas source to surface distance (SSD) was kept as 100 cm. The linear accelerator output was checked and monitored on a daily basis before each set of measurements. For both photon beams, the appropriate corrections were made in order to keep the machine output constant within 1% of the nominal value during the entire time period of the experiments.

Data were measured for both 6 and 18 MV photons. These measurements did not account for dose contributions from photoneutrons. As pointed out in the TG-36 report, the contribution of neutrons to the total PD is small near the beam edge. The National Council of radiation Protection[19] considers the risk of long-term biological effects of incidental from the linear accelerator to be negligible.

Results

The results of our measurements on surface dose with different wedge systes are shown in Tables 1 and 2 for the SSD of 85 and 100 cm respectively for both 6 and 18 MV photon beams. It can be seen from the tables that at a short SSD such as 85 cm, higher surface doses are produced by the lower wedges by the short wedge-to-skin distance. The HVL was estimated for 6 and 18 MV photons along the Central and off axis as in Figure 1 for the field size of 20 × 20 cm^2 with 45° upper physical wedge and compared with that of the enhanced dynamic wedge (EDW) as in Table 3. For physical wedged field, at heel edge side HVL value was high (17 cm) compared with the measured that of EDW (15.1 cm). It was noticed that, the HVL variation across the beam was significantly higher for 6 MV X-rays than for 18 MV X-rays.

The dependences of PD upon three different wedge systems for the field size of 15×15 cm^2 for 45° wedge are shown in Figures 2 and 3 for 6 and 18 MV photon, respectively. The measured wedge field data are compared with open field. From Figures 2 and 3, it was noticed that the lower wedge has the maximum variation of PD compared to other wedges.

Discussion

Surface and peripheral dose distributions from a dual energy linear accelerator can significantly affect the treatment techniques of patients with radiosensitive critical structures, which need to be protected. Premeasured surface and peripheral dose distributions can be used in the planning of radiation therapy treatments for such patients and to determine the need for additional shielding. The AAPM TG-36 data is often used in these situations. However, TG-36 data is not necessarily appropriate for linear accelerators equipped with MLCs and special measurements are needed to evaluate PD distributions from these machines individually.[18,20] This paper has presented surface and peripheral distributions for an Varian Clinac-DHX linear accelerator equipped with three different wedge systems.

Our results show that 65% surface dose is produced in a 6 MV beam at 85 cm SSD, for a 20 × 20 cm^2 field size, with 15° lower wedges. In contrast, the maximum surface dose produced by the upper and dynamic wedges are only 45% in the same geometry. Moreover, the 18 MV beam produces as much as 68% surface dose at a 85 cm SSD with the 15° lower wedge, for a 20 × 20 cm^2 field. Such a beam geometry is often found in a four-field box treatment of the rectum with an isocentric setup, where the field size to cover the rectum and all iliac nodes can be 16.5 × 20 cm^2, and therefore warrants special attention. The maximum surface dose of 70% in an 18 MV beam, in this geometry is produced by the 45° lower wedge for a 20 × 20 cm^2 field. The maximum surface doses produced by the upper or dynamic wedge in this beam arrangement are both approximately 40%, representing an reduction by a factor of nearly 2. Our measurement for the lower wedges agree well with those of Ocheran *et al*[21] and Li *et al*.[2] As they pointed out, the higher surface doses produced by

Table 1: Percent surface dose at source to surface distance = 85 cm, in 6 and 18 MV beams for three wedge systems

Wedge		*Collimator setting (cm × cm)*					
		6 MV Percent surface dose			*18 MV Percent surface dose*		
		10×10	*15×15*	*20×20*	*10×10*	*15×15*	*20×20*
15°	Upper	35.8		42.9	24.1		42.7
	Dynamic	38.6		48.6	27.1		43.7
	Lower	44.9		65.5	38.2		68.4
30°	Upper	34.6		45.9	24.4		44.1
	Dynamic	38.2		48.7	27.4		45.6
	Lower	43.8		59.3	38.2		63.9
45°	Upper	30.7		40.6	23.0		42.1
	Dynamic	38.6		55.6	27.0		43.1
	Lower	40.5		62.2	36.6		70.6
60°	Upper	29.9	35.6		24.0	33.9	
	Dynamic	38.32		50.1	27.3		44.0
	Lower	40.3	53.5	53.5	38.7	57.3	
Open field		38.4		48.5	27.0		42.9

Table 2: Percent surface dose at source to surface distance = 100 cm, in 6 and 18 MV beams for three wedge systems

Wedge		*Collimator setting (cm x cm)*					
		6 MV Percent surface dose			*18 MV Percent surface dose*		
		10x10	*15x15*	*20x20*	*10x10*	*15x15*	*20x20*
15°	Upper	35.2		41.6	21.0		35.4
	Dynamic	38.3		47.6	25.6		40.6
	Lower	38.5		52.9	28.8		48.1
30°	Upper	33.3		42.6	20.9		35.8
	Dynamic	38.0		47.7	25.5		40.7
	Lower	36.8		52.3	26.2		48.1
45°	Upper	29.8		37.8	20.4		34.9
	Dynamic	38.5		48.4	25.5		40.5
	Lower	34.8		48.7	26.0		49.0
60°	Upper	29.2	33.8		20.9	28.7	
	Dynamic	38.5		48.9	25.4		41.5
	Lower	33.2	41.9		27.0	39.4	
Open field		38.3		47.6	25.3		40.2

Table 3: Comparision of half value layer in water (cm) of 45° upper physical wedge and enhanced dynamic wedge for 6 and 18 MV beams

Position	*6 MV*		*18 MV*	
	P W	*EDW*	*P W*	*EDW*
A	17.0	15.1	28.0	27.5
B	17.0	15.2	27.8	27.4
C	17.0	15.9	28.5	27.7
D	17.2	15.7	28.5	27.8
E	16.4	15.5	28.5	27.7
F	16.8	16.0	28.4	27.9
G	16.7	15.8	28.4	28.0
H	16.4	15.2	28.0	27.5
I	16.2	15.0	27.5	27.0
J	15.2	14.5	27.0	26.6
K	15.2	14.2	27.0	26.5

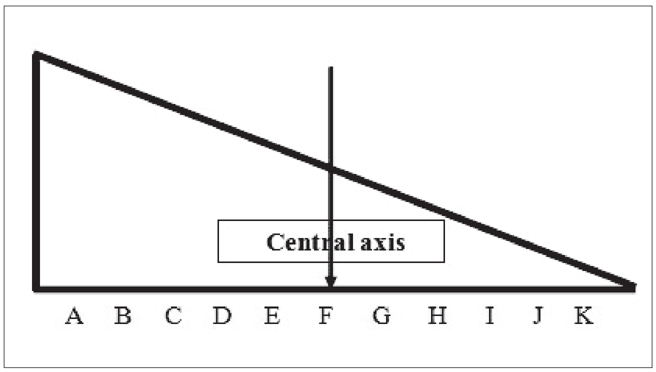

Figure 1: HVL measurement position identification of 45° physical and enhanced dynamic wedges for 6 and 18 MV beams (A to K distance is 36 cm)

the lower wedges may actually be beneficial when treating the breast with isocentric tangential beams. Due to the variation of thickness of the physical wedge from heel to toe end there may be a differential hardening of the incoming beam, whereas in the case of EDW, there would not be any differential hardening due to the uniform thickness of the jaws. The observed difference of change in the HVL value could be due to differential hardening of the beam with the physical wedge.

Shearazi and Kase[22] measured the effects of wedge filters on the PD and showed that a conventional wedge filter can elevate the PD by factors of 2--4 over that for the open filed, depending on the wedge angle. From our measurement, the influence characteristics of three different wedges on PD, it was noticed that PD was higher for all three wedges when compared to open field. Comparing the wedges, the PD was less for the EDW when compared to the both upper and lower physical wedges. The reason could be that EDW is placed at a considerable distance from patient and it does not have

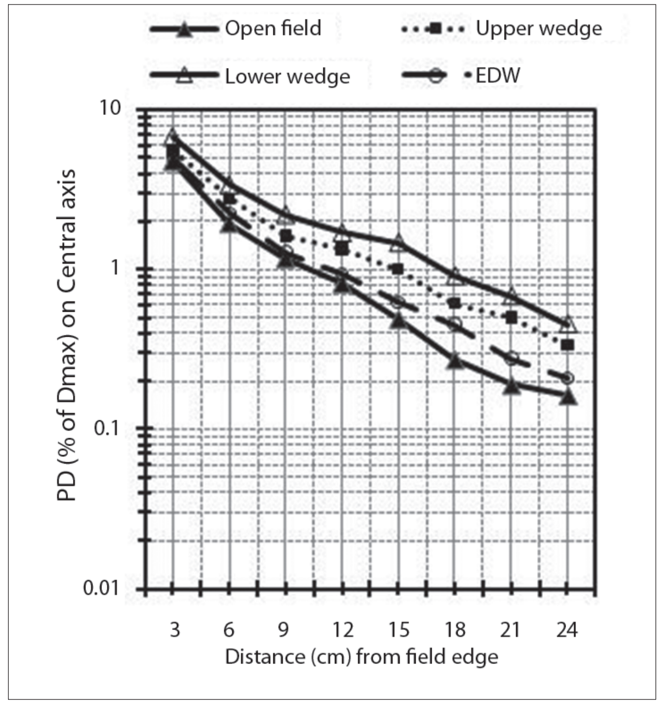

Figure 2: Peripheral dose comparison between three different type of wedge (45°) systems for 6 MV X-rays for the filed size of 15×15 cm²

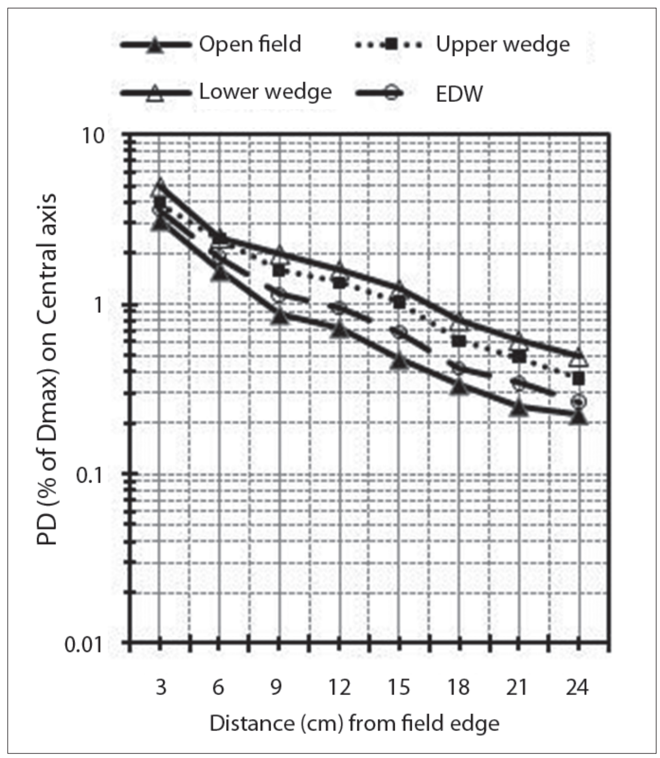

Figure 3: Peripheral dose comparison between three different type of wedge (45°) systems for 18 MV X-rays for the filed size of 15×15 cm²

varying physical thickness as that of the physical wedge. The differential thickness across the physical wedge would result in more scattered radiation being produced. As a result we observe more PD with lower physical wedges than that of upper one, which was expected due to more scattering at a less distance from the measuring point.

Conclusions

The three wedge systems discussed in this work possess vastly different physical and dosimetric characteristics. These differences will have a direct impact on the choice of the wedge system to be used for a particular treatment. Due to incompatability of the upper physical wedge with the cerroband blocks, it can be used in fields delineated by the collimator jaws or MLC. However, it has advantage of providing patient clearance than the lower wedge systems, in additon to producing smaller surface and peripheral dose. The EDW system produces nearly identical surface and peripheral doses as the open field, in addition to maintaining wedge-shaped dose profiles that are independent of field size. Complete knowledge of the dosimetric characterisitics, including the surface and peripheral doses, is crucial in proper choice of particular wedge systems in clinical use.

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