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Assessment of variation of wedge factor with depth, field size and SSD for Neptun 10PC Linac in Mashhad Imam Reza Hospital

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ABSTRACT

Background: In radiotherapy, wedge filters are used for optimizing the tumor dose distribution in patients. The attenuation in beam intensity due to the presence of wedge filter is compensated by means of a wedge factor measured at the central axis of the beam. The field size, depth and SSD dependence of wedge factor have been assessed for 9MV radiations of Neptun PC linear accelerator.
Materials and Methods: Wedge factors (WF) at different SSD, field size (FS) and depth (d) in water were measured for 8 steel wedges with different sizes and angles of 15, 30, 45, and 60 degree. Experimental data were obtained using Neptun 10PC, Linac 9MV X-ray machine, a 3D water phantom, dosimeters and an electrometer. To study the effect of field size on WF, the wedge factor was measured for square field sizes from 5×5 to 20×20 cm, with 1 cm increment intervals for all wedges; and, at the depth of 10 cm, SSD of 100 cm with monitor unit (MU) of 80. Effects of depth on WF were studied by measurement in various depths from 3-19cm for all wedge angles at SSD of 100cm, field size of 10×10cm and 80 MU irradiation. Effects of SSD on WF were investigated by a variation of SSD from 90-110cm with 5cm increment intervals; while the dosimeter was set at depth of 10cm and field size of 10×10cm were irradiated for 80MU.
Results: Linear dependence of WF with field size and depth of measurements were confirmed with 95% certainty. Shapiro-Wilk test, showed that the residual data of the regression tests have normal distributions (P>0.05). There was also found no linear relationship between WF and SSD (P>0.05).
Conclusion: WF has linear dependence with field size and depth of measurements, but the rate of variations are less than 2.2% per 10cm variation in field size and less than 1.3% per 10 cm variation in depth of measurements, therefore, correction of WF for field size and depth of treatments in clinical trials is negligible. *Iran. J. Radiat. Res., 2004; 2 (2): 53-58*

Keywords: *Wedge factor, wedge filter, linear accelerator.*

INTRODUCTION

In radiotherapy, using wedge filter is a common technique for modifying iso-dose curves and it optimizes the tumor dose distribution in patients. There are generally two different methods for applying the filters: external mounting on the treatment head of machine (typically 15, 30, 45 and 60 degree), and internal filter (65 degree), which is electronically moved in and out of the beam, and different wedge angles are obtained by weighted superposition of wedged and open beam. As the wedge filter reduces the beam intensity and can result in large errors in delivering dose; the precise wedge transmission factor or wedge factor (WF) needs to be determined and accounted for the computation of time setting or monitor unit to compensate the attenuation by extending the radiation time. It is important, therefore, to assess and generalize any variation to wedge factor resulting from field size, depth,

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and SSD to be used in delivering the exact prescribed dose to patient.

Palta *et al.* (1988) and Lee *et al.* (1989) have studied field dependence of wedge factors and concluded that the dependence of the WF on field size is attributed to the changes in phantom scatter, as well as to the change in collimator scattered photon that reaches the point of measurement.

The depth dependence of the WF have been studied since many years ago, by Sewchand *et al.* (1978), and Wu *et al.* (1984) and was attributed to the hardening of the incident beam passing through the wedge filter which absorbs and/or scatter the low energy photons. Kalend *et al.* (1990) have shown that depth dependence of the WF caused by the dose gradient due to increase phantom scattering is as significant as the beam hardening, especially for low energy X-ray produced by Linac.

The purpose of this study was to assess the dependence of WF on the most commonly used treatment depth, field size and SSD, to inform the physicist from the magnitude of the various effects of wedge filters used in their clinical treatment planning; and to provide a simple algorithm to predict the precise amount of corrected wedge factor needed for their clinical routines.

MATERIALS AND METHODS

Wedge factor at a depth (d) in water for a field size (FS), and at a certain SSD was defined as the ratio of the dose with the wedge beam, D_w (FS, d), to the dose with open beam, D_o(FS, d).

In this study, experimental data were obtained using Neptun 10PC Linac 9MV X-ray machine, a 3D water phantom (Scanditronix 50×50×50 cm), two RK (0.12cc) ionizing chamber as a reference and field dosimeters, electrometer (Scanditronix model DPD510), and 8 steel wedges with different sizes and angles which are numerated based on their maximum field sizes as shown in table 1.

To set the system, the phantom is placed horizontally in position at SSD of 100 cm and adjusted so that the phantom index overlapped with the light field index of the machine; then the field dosimeter is put at the centre of the field (overlapping light field index with white spot on the dosimeter) and reference dosimeter at the corner of light field, as is shown in figure 1. Accuracy of the obtained data were controlled by measuring the depth dose profiles, inline and cross line, prior to the measurements, with RFA-Plus software and performing all quality controls which might have affected to the measurements directly or indirectly.

Table 1. Physical characteristics of the external wedges used for Neptun 10PC Linac.

Wedge No.	Wedge Angle (degree)	Max. thickness (cm)	Max. width (cm)	Max. length (cm)	Max. field size at isocenter (cm×cm)
1	15	1.2	15.2	16	20×20
2	30	1.8	11.4	16	15×20
3	30	2.4	15.2	16	20×20
4	45	2.0	7.6	16	10×20
5	45	3.0	11.4	16	15×20
6	45	3.9	15.2	16	20×20
7	60	3.0	7.6	16	10×20
8	60	4.5	11.4	16	15×20

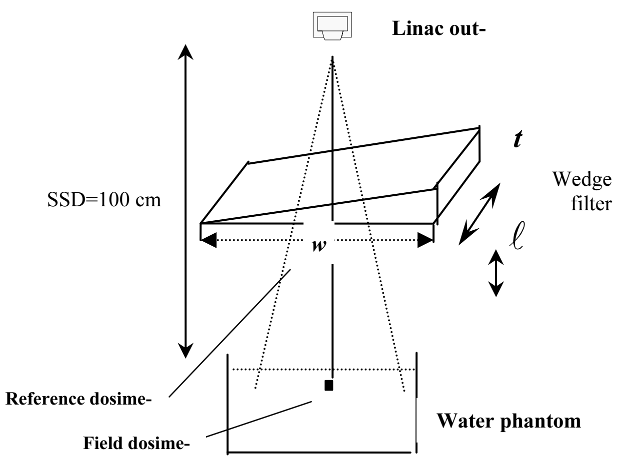

Figure 1. Measurement configuration diagram of the system for controlling the accuracy and measuring WFs.

To study the effect of field size on WF, the wedge factor were measured for square field sizes from 5×5 to 20×20 cm with 1 cm increment intervals at wedge angles of 15, 30, 45, and 60 degree, and at the depth of 10 cm, SSD of 100 cm with monitor unit of 80. In this study, the entire field sizes were squared, but the rectangular field size allowable for each wedge could be used if the side of field sizes were derived from the equivalent Square as discussed by Popescu *et al.* (1999).

Effects of depth on WF were studied by measurement in depths of 3, 5, 7, 10, 13, 16 and 19 cm, with wedges 15^o (No.1), 30^o (No.2), 45^o (No.4) and 60^o (No.7), SSD of 100cm, field size of 10×10cm, and 80 MU irradiation.

Effects of SSD on WF were investigated by a variation of that from 90-110cm with 5cm increment interval, while the dosimeter was set at depth of 10cm and field size of 10×10cm, irradiated for 80MU.

RESULTS AND DISCUSSION

Measurements of the wedge factors were performed by studying the output charges of the field detector, alternatively for wedged and open beams, and for calculating the ratio of the wedged to open beam measurements. The results of WF, using various field size, depth and SSD are shown in tables 2, 3 and 4 respectively.

Table 2. Wedge factor variations with field size (side of square field / cm) for Neptun 10PC Linac 9MV radiation.

Side of	15^o	30^o		45^o			60^o	
F.S. cm	No.1 20×20	No.2 15×20	No.3 20×20	No.4 10×20	No.5 15×20	No.6 20×20	No.7 10×20	No.8 15×20
5				0.747			0.655	
6	0.838	0.775		0.749			0.655	
7				0.748			0.655	
8	0.84	0.775		0.750			0.656	
9				0.750			0.657	
10	0.84	0.776		0.753			0.659	
11					0.664			0.537
12	0.841	0.776						0.539
13					0.665			0.541
14	0.842	0.779			0.666			0.541
15					0.668			0.543
16	0.842		0.717			0.591		
17			0.719			0.592		
18	0.844		0.719			0.594		
19			0.722			0.595		
20	0.846		0.723			0.598		

Table 3. Wedge factor variations with depth for Neptun 10PC Linac 9MV radiation.

depth cm	15^o No.1	30^o No.2	45^o No.4	60^o No.7
3	0.830	0.772	0.749	0.656
5	0.834	0.772	0.752	0.659
7	0.834	0.769	0.753	0.659
10	0.837	0.772	0.755	0.662
13	0.837	0.774	0.755	0.665
16	0.838	0.776	0.759	0.669
19	0.839	0.779	0.759	0.670

Table 4. Wedge factor variations with SSD for Neptun 10PC Linac 9MV radiation.

SSD cm	15^o No.1	30^o No.2	45^o No.4	60^o No.7
90	0.833	0.768	0.757	0.664
95	0.834	0.768	0.757	0.663
100	0.831	0.766	0.757	0.662
105	0.832	0.765	0.754	0.663
110	0.830	0.767	0.756	0.662

In the literature, wide variations of WF with FS has been reported, from no clear dependence reported by Dean (1991) and Cozzi *et al.* (1996) to more than 10% variation by Palta *et al.* (1988), Thomas (1990) and Podgorsak *et al.* (1993). In this study, various FS from 5×5 to 20 ×20 cm for angles of 30º, 45º and 60º, and 2 wedges with different maximum width were used respectively. As the central thickness of each wedge t/2, with angle α, is dependent on its maximum width (w), by t=w.tan α, therefore, measured WFs for a given angle and FS, by two wedges with maximum width w_2 and w_1, caused the wider wedge to attenuate the wedged beam more by a factor of $e^{-\mu\Delta t/2}$; where μ is the attenuation coefficient of the wedge and Δt is the difference between their central thicknesses. Hence, as shown in table 2, for given angles of 30º, 45º or 60º the wider the wedge, the lower the measured WF. Total variation of WF in the situation used in this study, varied from 0.008 to 0.006 (0.07% to 0.22% per cm×cm variation in field size) from thinnest to thickest filter; therefore, any correction of WF in clinical trials (for maximum 10 cm variations in field size) seems to be negligible (maximum 2.2%) (Niroomand-Rad *et al.*1992, Heukelom *et al.*1994). Wide variation of WF with depth (from 2% to 10%) has been reported in the literature; however in this study WF dependence per 10cm variation in depth varied from 0.68% for 15º (no.1) thin filters to 1.3% for 60º (no.7) thick filters.

The existence of linear relation between WF and different variable factors, FS, depth and SSD, were investigated by statistical regression test; and also to ensure of the normalization of the residual data distributions, Shapiro-Wilk test was used.

To investigate the FS dependence of WF, first, the measured WFs were corrected for the maximum width of the wider available wedges, and then the statistical regression test, and also Shapiro-Wilk test were applied. The results and the regression lines are shown in figure 2.

P-values of the regression test for all wedge filters were less than 0.05; therefore, linear dependence of WF with field size was confirmed with 95% certainty. Also, the p-values of the Shapiro-Wilk test were more than 0.05, which meant that the residual data of the regression tests had normal distributions. Equation of the regression lines and regression coefficients are shown in figure 2.

Linear dependence of WF with depth and SSD for 15º (No.1), 30º (No.2), 45º (No.4) and 60º (No.7) wedge filters, shown in tables 3 and 4, were also investigated with regression and Shapiro-Wilk tests. The linear dependence with 95% of certainty, (p-values less than 0.05) was confirmed only for depth. P–values for SSD variations for all wedge filters were more than 0.05; therefore, there is no linear relation between WF and SSD. In fact, an inverse linear dependence between WF and SSD has been found by the authors for ^{60}Co gamma radiations, which is attributed to attenuation of collimator scattered photons with increasing SSD. That was due to the fact that for ^{60}Co radiation, as reported by Kalend *et al.* (1990), there was no beam hardening effects due to presence of wedge filter, while it existed for linac x-rays and could therefore diminish the

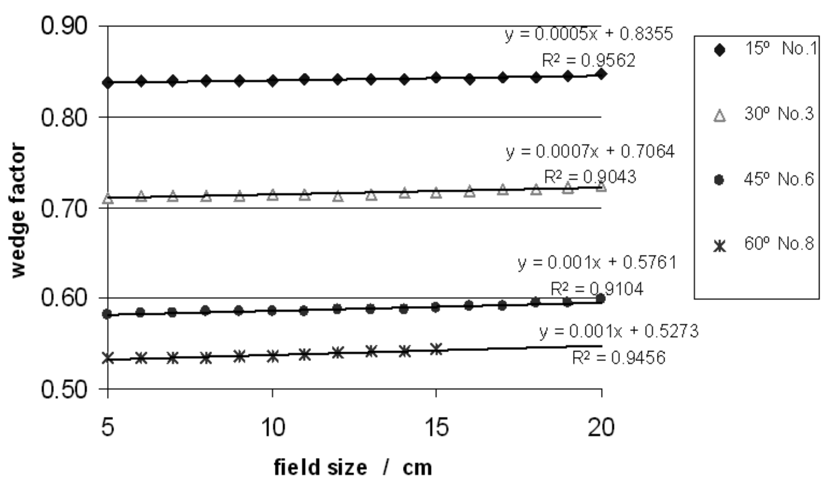

Figure 2. Variations of wedge factor with field size for 9MV radiation from Neptun 10PC Linac.

dependence of WF to SSD. The lack of WF dependence with SSD was confirmed by Popescu *et al.* (1999) who studied different wedge (external and internal) filters with photon energies 4-24 MV.

The linear dependence of WF with field size and depth and also lack of dependence with SSD were in agreement with the results reported by Popescu *et al.* (1999) and Niroomand-Rad *et al.* (1992). The regression line of WF with field size, FS, for wedge No.1 (15º) at the depth of 10 cm, field size of 10×10 cm, and SSD=100cm, can be expressed as:

$$WF_c = WF_{(10\times10,\ 15^o)}\,[1 + a\,(FS\text{-}10)]$$

Where WF_c is the corrected WF for any field size, FS, and a=0.0005 is the slope of regression line shown in figure 2. In a similar way the WF at different depth can be calculated by the following formula:

$$WF_c = WF_{(10\times10,\ 15^o)}\,[1 + b\,(d\text{-}10)]$$

Where WF_c is the corrected WF for any depth, d, and b=0.0005 is the slope of regression line shown in figure 3. To merge these equations and modify that for other filters, the difference between central thicknesses of the filters must be taken into account. This is performed by the following formula:

$$WF_c = WF_{(10\times10,\ 15^o)}\,e^{-\mu(t-1.2)/2}\,[1 + a\,(FS\text{-}10)] \times [1 + b\,(d\text{-}10)]$$

Where, t, is the maximum thicknesses (from table 1) and μ (with the average of 0.27 cm^{-1}) is the linear attenuation coefficient of the filters. The value of a, and b for different wedge angles are derived from figures 2 and 3, and shown in table 5.

All the measured data shown in tables 2, 3 and 4 were obtained using this formula with maximum error of less than 1%. Therefore, this formula can be used by physicist to predict the precise amount of corrected wedge factor of any filter needed for their clinical routine treatments.

Table 5. Slope of regression lines of wedge factor with field size and depth for different filters Used with Neptun 10PC linac 9MV radiation.

Wedge angle	a	b
15º (No.1)	0.0005	0.0005
30º (No.2)	0.0007	0.0005
45º (No.4)	0.001	0.0006
60º (No.7)	0.001	0.0009

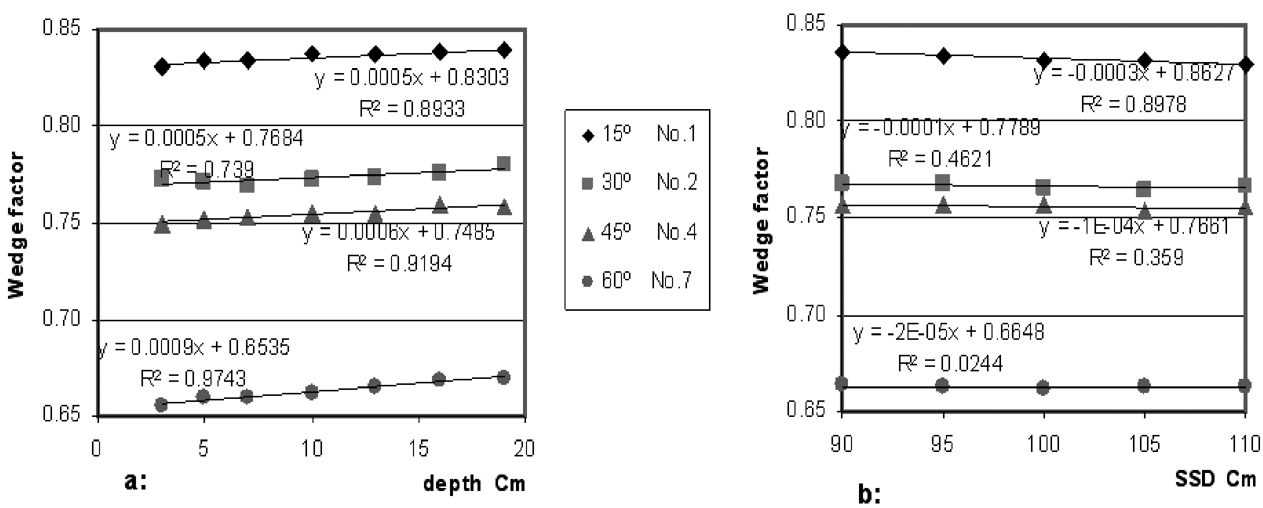

Figure 3. Variations of wedge factor with

CONCLUSION

Although the WFs have linear dependence with field size and depth of measurements, the rate of WF variations at the situation used in this study, are less than 1.72% per 10cm variation in field size, and less than 0.87% per 10 cm variation in depth of measurements. So any correction of WF for clinical trials is negligible. This is in agreement with the ICRU report 24 (1976) which neither specifies measurements of no depth or field size.

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