RECOMMENDATION FOR DEPTH MEASUREMENT OF WEDGE TRANSMISSION FACTORS FOR HIGH ENERGY PHOTON BEAMS

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ABSTRACT

In clinical practice, it is often assumed that wedge transmission factor (WTF) is independent of depth. Measurements have been experimented which demonstrated a clinically significant variation in WTF, as much as 6.8% for A 60° wedge between 5 and 15 cm. depth. The measurements were performed for various field sizes at depth of maximum dose (d_{max}), 5, 10 and 15 cm. depths. It made with ionization chamber in solid phantom with 80 cm. SSD for Co-60, and 100 cm. SSD for three linear accelerator x-ray beams with energies of 6, 10 and 15 MV. From our experiments, these systematic measurements on WTF show that in general there is a definite dependence at various depths varies with beam energy and wedge angle. And the recommended depth of measurement should be 5 cm depth for Co-60 gamma ray, 6 and 10 MV x-rays, and 5 cm or 10 cm depth for 15 MV x-rays.

INTRODUCTION

Wedge filters are routinely placed into the path of high energy photon beams to modify the isodose distributions which are invaluable in the dose treatment planing to achieve homogeneous dose distribution and the presence of wedge filter decreses the beam intensity and this must be taken into account in the treatment dose calculation. The change in the beam is characterized by relative isodose distribution and a WTF. ICRU[1] defines the wedge transmission factor (WTF) or wedge factor (WF) as the ratio of dose in phantom at a point on the central axis with and without wedge. In clinical practice, it is assumed that WTF is independent of depth and field size. In many institutions, a single value of WTF is determined at a specified reference depth such as depth of maximum dose (d_{max}) and reference field size such as $10x10^2$ cm field. It is then used in the calculation of monitor unit settings or timer setting for all wedge fields. Palta et al[2] found that the error for 4 or 6 MV x-rays when using a single WTF with 60° wedge could reach 3.5% for a $16x16^2$ cm field and 7% for a $20x20^2$ cm field. Our previous study,[3] the result demonstrated variation in the WTF of up to 5%, 5.5%, 6% and 4.5% for Co-60 gamma rays, 6, 10, and 15 MV x-rays respectively, for field size of 22x22 cm^2 moreover, for 25x25 cm^2 field introduced error of up to 7.6% for 6 and 15 MV x-rays.

To determine whether WTF should be measured as function of depth, McCullough et al[4] reported that for 4 to 10 MV x-ray beams and for depths less than or equal to 10 cm, the WTF at

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depth was less than 2% different from that determined at d_{max}, for a nominal wedge angle in excess of 45° with depth greater than 10 cm, the WTF at depth differed from the WTF determined at d_{max} by up to 5%. However it is unclear where the depth of measurement should be used for calculation or dose planning when wedge filters are used to modify the photon beams

The purpose of this work was to investigate and examine systematically the depth dependence of in phantom WTF for Co-60 gamma rays, 6, 10 and 15 MV x-rays and 15°- 60° wedges (norminal wedge angle) and to use these results to suggest the depth of WTF measurements.

MATERIALS AND METHODS

WTF measurements were performed to Co-60 (Theratron 780 C), 6 MV x-rays (Siemens-MD Mevatron), 10 MV x-rays (Mitsubishi-ML-15 M) and 15 MV x-ray (Siemens-KD Mevatron) using standard wedge filters provided by the manufacturer with nominal wedge angle of 15°, 30°, 45° and 60°. For all wedge filters, transmission measurements were obtained with a Farmer ionization chamber in solid water phantom coupled to Farmer electrometer (model 2570/1). all measurements were performed at d_{max} (0.5 cm for Co-60, 1 cm for 6 MV x-rays, 2.3 cm for 10 MV x-rays and 3 cm for 15 MV x-rays), 5, 10 and 15 cm depths for various field sizes (from 5x5 cm^2 to 15x15 cm^2), using a source surface distance of 80 cm for Co-60 and a target surface distance of 100 cm for linear accelerators. To confirm that the wedge was centered,the measurements with wedge filters were repeated for 180° collimator rotation. For each beam energy, measurements for open fileds were performed at the same depth and field size. The WTF at any given depth and field size was determined as the ratio of reading with and without wedge.

RESULTS AND DISCUSSION

The dependence of WTF on depth of measurement is shown in table 1 for Co-60, 6, 10 and 15 MV x-rays respectively. The WTFs were normalized to the mean of each given field size and for each given energy and wedge angle. The results of this study showed dependence on depth. If the WTF from one depth of measurement were to be used for each wedge it seems that the measurement for each given field size at a depth of 5 cm would represent a good choice for Co-60, 6 and 10 MV x-rays, and the recommendation of measurement depth for 15 MV x-rays should be 5 or 10 cm depth. For our experiment, we also studied the variation of the WTF with depth. Using a depth-normalized relative wedge factor (RWF_d) for various depths, d and it was defined as

$$RWF_d = WTF(d,A)/WTF(d = 5\text{ cm}, A)$$

Where RWF_d provided a direct estimate of depth dependence of the WTF for each field size relative to that determine at 5 cm depth.

Table 2 presents a summary of the RWF_d for 15°- 60° wedge angles for various field sizes for Co-60, 6, 10 and 15 MV x-rays respectively. From the results, they are shown to be affected by hardening for x-rays and softening for Co-60 gamma rays.

For Co-60 gamma ray beams filtered by a wedge, the wedge effect on the beam spectrum, which is nearly monoenergetic, has been assumed to be minimum.[1] However Co-60 wedge transmission measurements were found to be increase with depth, as much as 3.3% for 60° wedge at 15 cm depth, It has been speculated that the depth dependence of a WTF in Co-60 beams may be due to secondary photons from the wedge filter itself, by compton scattering[5]

Table 1. WTF for Co-60, 6, 10 and 15 MV x-rays. Factors normalizedd to the mean value of WTF for each wedge filter.

Beam Energy	Depth (cm)	15° wedge 5x5 (cm^2)	15° wedge 10x10 (cm^2)	15° wedge 15x15 (cm^2)	30° wedge 5x5 (cm^2)	30° wedge 10x10 (cm^2)	30° wedge 15x15 (cm^2)	45° wedge 5x5 (cm^2)	45° wedge 10x10 (cm^2)	45° wedge 15x15 (cm^2)	60°wedge 5x5 (cm^2)	60°wedge 10x10 (cm^2)	60°wedge 15x15 (cm^2)
Co-60	0.5	0.994	0.992	0.997	0.988	0.986	0.992	0.993	0.996	0.998	0.969	0.963	-
(Theratron)	5.0	1.001	0.999	0.997	0.997	0.992	0.996	1.002	0.996	0.992	1.003	0.991	-
	10.0	0.999	0.998	1.005	1.003	1.006	1.008	0.999	0.998	1.003	1.017	1.022	-
	15.0	1.001	1.012	1.002	1.012	1.016	1.004	1.006	1.009	1.007	1.010	1.023	
	-												
6 MV	1.0	0.992	0.992	0.988	0.977	0.979	0.982	0.966	0.974	0.971	0.965	0.974	0.980
(Siemens)	5.0	1.002	0.999	0.998	0.990	1.002	0.996	0.977	0.992	0.989	0.991	0.995	0.972
	10.0	0.989	0.998	1.002	1.009	0.993	1.003	1.016	0.999	1.003	1.014	0.995	1.011
	15.0	1.018	1.012	1.013	1.025	1.025	1.019	1.021	1.035	1.038	1.030	1.037	1.038
	-												
10 MV	2.3	0.988	0.992	0.995	0.995	0.992	0.996	0.999	0.995	0.995	1.006	1.002	1.000
(Mitsubishi)	5.0	1.000	1.002	1.003	1.002	1.003	1.003	0.995	0.998	1.000	1.005	1.006	1.005
	10.0	0.998	0.999	0.997	0.996	0.994	0.993	0.995	0.995	0.996	0.985	0.985	0.985
	15.0	1.014	1.008	1.005	1.007	1.010	1.008	1.011	1.012	1.009	1.003	1.006	1.009
	-												
15 MV	3.0	0.995	0.991	0.992	0.995	0.995	0.993	0.990	1.000	0.991	0.983	0.979	0.979
(Siemens)	5.0	0.996	0.998	1.004	1.005	1.003	1.005	0.996	0.994	1.002	1.001	1.007	1.007
	10.0	1.002	0.997	0.994	0.999	1.002	0.998	1.010	0.995	0.999	1.009	1.003	1.007
	15.0	1.007	1.015	1.010	1.001	0.999	1.004	1.004	1.011	1.007	1.007	1.012	1.007

Table 2. RWF$_d$ 15°-60° (nominal wedgs angle for 5x5 to 15x15 cm. fields for Co-60 unit, 6, 10, and 15 MV x-rays. Factors normalized to 5 cm. depth.

Beam	Depth	15° wedge			30° wedge			45° wedge			60°wedge		
Energy	(cm)	5x5	10x10	15x15	5x5	10x10	15x15	5x5	10x10	15x15	5x5	10x10	15x15
		(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)	(cmxcm)
Co-60	0.5	0.993	0.993	0.999	0.991	0.994	0.997	0.990	1.000	1.006	0.966	0.972	-
(Theratron)	5.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-
	10.0	0.998	0.999	1.007	1.007	1.013	1.012	0.996	1.001	1.011	1.014	1.032	-
	15.0	1.005	1.013	1.005	1.016	1.024	1.009	1.004	1.013	1.015	1.008	1.033	-
	-												
6 MV	1.0	0.990	0.993	0.990	0.987	0.977	0.987	0.970	0.982	0.982	0.974	0.979	1.009
(Siemens)	5.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	10.0	0.987	1.000	1.004	1.020	0.991	1.007	1.019	1.007	1.014	1.024	1.000	1.040
	15.0	1.016	1.013	1.015	1.035	1.023	1.023	1.025	1.044	1.050	1.039	1.042	1.068
	-												
10 MV	2.3	0.988	0.990	0.992	0.993	0.988	0.993	1.004	0.997	0.995	1.001	0.996	0.995
(Mitsubishi)	5.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	10.0	0.999	0.997	0.995	0.993	0.990	0.990	1.000	0.999	0.996	0.980	0.979	0.981
	15.0	1.014	1.006	1.003	1.005	1.006	1.005	1.016	1.015	1.010	0.998	0.999	1.003
	-												
15 MV	3.0	0.999	0.993	0.988	0.996	0.992	0.988	0.994	1.007	0.989	0.982	0.972	0.973
(Siemens)	5.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	10.0	1.006	0.999	0.989	0.995	0.999	0.993	1.014	1.001	0.997	1.008	0.996	1.000
	15.0	1.011	1.017	1.006	0.996	0.996	0.999	1.008	1.018	1.008	1.005	1.005	1.000

For x-ray bems, the variation of the WTF with depth has been attributed to the effect of the beam hardening which results from preferential absorption of low energy photon component in the beam.[5,6,7] The low energy photons are attenuated much more than high energy photons. This can explain the greater changes were found up to 6.8% for 6 MV x-rays at depth of 15 cm and for 60° wedge. The beam hardening effect expected to be smaller for 10 and 15 MV x-ray beams.

CONCLUSION

In this experiment, we have studied the characteristics of depth dependence of the WTF for various energy beams. Based on the analysis of RWF_d, there is a definite dependence of WTF upon the depth of measurement. The degree of dependence varies with beam energy and wedge angle. For 6 MV x-rays, the deviation increase with depth up to 6.8% at 15 cm for 60° wedge, indicating some hardening of the beam by the wedge filter. The most important finding in this study is that the suggestion for depth of WTF measurement for Co-60, 6 and 10 MV x-rays should be 5 cm, and 15 MV x-rays should be measured at 5 or 10 cm depth.

As pointed out in our study[3] and other investigators,[2,4,6,7] it is clearly necessary to take the dependence of the WTF on field size and larger depth into account in clinical dose calculation.

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