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A comparison study of out-of-field photon dosimetry between two Varian linear accelerators

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SUMMARY

Purpose: The present study compares the components of field dose of two linear accelerators and quantifies (i) the variation of out-of-field dose with the detector, (ii) the phantom scatter, collimator scatter and head leakage contribution towards out-of-field dose for two linear accelerators (LINAC), and (iii) the variation of out-of-field dose with Field Size (FS)

Materials and Methods: The out-of-field measurements were obtained from Varian Unique Power Linear Accelerator (VUP) and compared with the Varian Truebeam® STx Linear accelerator (VTB) using PTW chambers of different volumes and slab phantoms. The measurements with different chambers were performed for 10 cm2×10 cm2 FS with VUP with collimators 00 and 900. The out-of-field dose components were measured for a small and intermediate FS for VUP and VTB. The measured results were compared with the TPS calculated.

Results: Comparing the out-of-field dose contribution semi flex showed a higher dose than other chambers. Compared to the individual scatter component, the phantom scatters component shows high with Semi flex chamber, the collimator scatter with the farmer, and head leakage with Semi flex. With collimator rotation of 900, Semi flex and pinpoint showed an increase in out-of-field dose concerning collimator zero. All the components of out-of-field dose increase with FS. When comparing the scatter components of two Linacs, VUP showed a lesser scatter than VTB.

Conclusion: Higher out-of-field was observed with Semi flex chamber with a collimator 90° and with a larger FS. Among the machine, VUP showed a lesser scatter factor. From TPS measurements, it was clear that TPS was not modelled for collimator scatter and head leakage.

Key words: out of field dose, scatter factor, Semi flex chamber, non-target dose

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INTRODUCTION

The goal of External Beam Radio Therapy (EBRT) treatment is to deliver a conformal and focused radiation beam to a target volume to achieve therapeutic benefit within the Clinical Target Volume (CTV). The uncertainties in positioning require an additional margin for CTV and forming Planning Target Volumes (PTV). The PTV refers to the volume of tissue planned to receive the prescribed dose. The advanced treatment techniques are used to deliver a conformal higher dose to the tumour while minimizing adjacent normal tissue doses with the help of beam shaping. Deterministic effects can be avoided by sparing the normal structures, but it may not reduce the stochastic effects.

Radiation has little effect on tissue outside of the PTV. Non-target doses are split into two categories:

a) A non-target dose that is within a primary field border, such as an entrance and exit dose along the beam path, is referred to as an "in-field non-target dose"

b) "Out-of-field non-target dose" is -a non-target dose that is deposited by stray, or secondary radiation that is not only outside of the PTV but also outside of any primary field edge dose [1].

Any "non-target" radiation should be minimized in radiation therapy as it offers no therapeutic benefit. However, during treatment, unwanted doses are delivered to the non-target volumes in the body. These doses are known as out-of-field doses arising from outside the primary beam. Non-target dose or out-of-field dose can be classified into 3 dose levels. High dose (>50% of the prescribed dose), intermediate dose (5%-50% of the prescribed dose), and low dose (<5% of the prescribed dose). Because of cancer screening and contemporary medicines, the possibility of late consequences from secondary radiation may be more apparent today in the modern day. Many published studies have reported non-target doses from various radiotherapy approaches [1-3]. Dose to the non-target can be reduced in many ways, such as minimizing the size of CTV or PTV by reducing the field size, treatment technique, treatment energy, beam angle, Multi Leaf Collimator (MLC), jaw tracking, and machine shielding. Outfield-field doses arise from several contributions such as head leakage, scattering at the beam collimators, and scattering from the patient body or phantom. Thus the out-of-field dose is the sum of phantom scatter, collimator scatter, and head leakage.

Total out-of-field dose (T)=Head leakage (L)+Collimator scatter dose (S)+Phantom scatter dose (P).

Radiation scatters from a patient or phantom are the leading cause of out-of-field dose near the treatment field edges. Phantom scatter depends on the field size and patient characteristics. Leakage radiation has a significant contribution in large distances. MLC may enhance the leakage radiation, and collimator scatter contribution by increasing the Monitoring Unit (MU) and treatment time.

The Treatment Planning System (TPS) is used in EBRT to calculate the treatment dose accurately but does not correctly calculate the dose outside the primary beam due to less optimization. Moreover, the out-of-field dose due to photon, proton, and neutron is a challenging issue. For a 6 MV beam, the average energy outside the treatment field is between 0.2 MeV to 0.6 MeV. Many studies indicated the inaccuracy of out-of-field dose calculation algorithms in TPS systems and different cancer patients. Cyriac et al. (2015) studied the accuracy of out-of-field dose calculation by measuring the components separately using the Oncentra Planning system [4]. Directing the beam to the phantom gives all the 3 out-of-field components, and directing the beam out of the phantom provides leakage and collimator scatter. Leakage radiation is measured by closing MLC completely. Nevertheless, the obtained results show poor calculation in the treatment planning system.

J M Bordy et al. in 2013 also did a similar study of out-of-field dose measurement [5]. Measurements are the same as that of cyriac et al., and they observed that the individual components of out-of-field depend on energy [4].

A.M. Abdelaal et al. 2017 reported a higher out-of-field dose with a pinpoint chamber, and they studied the out-of-field dose with the Source to Surface Distance (SSD), field sizes, energy, and depth [6]. Based on this literature review, there is significantly less or no information on comparing the out-of-field dose among machines. Abdelaal et al. in 2020 reported a higher out-of-field dose with the Markus chamber [7]. So this study is to compare all the scatter components of out-of-field dose of two linear accelerators, Varian Unique Power (VUP) and Varian True Beam® STx (VTB), for small and intermediate field sizes. Along with that, our study extended to find a suitable ionization chamber for the measurement of dose outside the beam.

MATERIALS AND METHODS

The measurements were performed using 6MV photon beams on VUP having 120 Millennium (Mi-MLC) and VTB with High Definition MLC (HD-MLC). PTW's slab phantoms along with farmer-type chamber, Semi flex chamber and pinpoint chamber, and Unidose Electrometer were used for measurements. VUP is the single low photon (6 MV) linear accelerator with 60 pairs of Millennium MLC attached to the gantry head as tertiary collimators with 0.5 cm leaf resolution at the isocentre. VTB is a high-energy linear accelerator that can produce 6 MV, 10 MV, and 15 MV flattened beams, 6 and 10 flattening filter-free photon beams, and four electron energies (6 MeV, 9 MeV, 12 MeV, and 15 MeV). VTB has equipped with an HD-MLC with 60 pairs with 2.5 mm leaf width in the central region for 8.0 cm and 5 mm leaf width in the periphery. Semi-flex ionization chamber 31010 (PTW, Germany) is a vented cylindrical ionization chamber with a volume of 0.125 cc that operates up to ± 400 V. The sensitive volume has a radius of 2.75 mm and a length of 6.5 mm with a total wall area density of 78 mg/cm^2. The central electrode is Al 99.98 with a diameter of 1.1 mm.

The farmer ionization chamber is a vented cylindrical ionization chamber with a sensitive volume of 0.6 cm^3 and is used for absolute dosimetry. The reference point of the chamber is at 13 mm from the tip of the chamber and is operated up to ± 400 V. It has a dimension of the sensitive volume of a radius of 3.05 cm and length of 23.0 mm, and a total wall density of 56.5 mg/cm^2. The central electrode is Al 99.98 with a diameter of 1.15 mm. The pinpoint ionization chamber, which is also a vented ionization chamber, is used for small field measurements are operated at a nominal voltage of 300 V. This dimension of the sensitive volume of the radius is 1.45 mm and length of 2.9 mm, and a total wall area density of 84 mg/cm^2. The central electrode is Al 99.98 with a diameter of 0.6 mm.

All measurements were performed in slab phantoms at 5 cm depth with a source-to-surface distance of 95 cm. The dose at 5 cm depth for 100 MU is noted for all chambers for field size 10 cm^2×10 cm^2. To duplicate the clinical scenario, the field size was defined by MLC and jaws. The dose at a point outside the field is the sum of phantom scatter, collimator scatter, and head leakage. The total dose was measured from 1 cm from the field border to 5 cm, as in Figure 1.

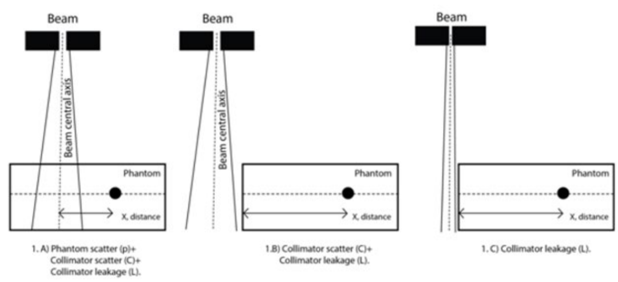

Fig. 1. Measurement setup for scatter dose

The collimator scatters with head leakage components were measured by keeping the chamber at 5 cm depth and 1 cm from the field border. In the same setup, the collimator leakage was also measured. The phantom scatter, collimator scatters, and collimator/head leakage components were measured on VUP 6MV beams with all three ionization chambers with collimator 0° and 90° to know the variation of these components with chamber and with collimator orientation. All mentioned scattering components are measured for LINAC-2 with collimator zero with Semi flex chamber for 3 cm^2×3 cm^2 and 10 cm^2×10 cm^2.

To know the variation of out-of-field dose with chambers, we performed all the measurements with Farmer chamber, Semi flex chamber, and Pinpoint chamber at 5 cm depth with collimator and gantry at 0° and calculated the phantom component,

Tab.1. Phantom scatter contribution (%) concerning isocenter dose for 6MV beams with different detectors

Chamber Type	Collimator angle	Distance from field border (cm)				
		1	2	3	4	5
Farmer	0˚	3.464	2.163	1.486	1.083	0.8
	90˚	3.382	2.079	1.471	1.068	0.8
Semi flex	0˚	5.474	2.982	1.855	1.3	0.96
	90˚	5.559	2.943	1.828	1.318	1.001
Pinpoint	0˚	5.01	2.722	1.668	1.181	0.936
	90˚	5.318	3.006	1.669	1.193	0.972

Tab.2. Collimator scatter contribution (%) concerning isocenter dose for 6MV beams with different detectors

Chamber Type	Collimator angle	Distance from field border(cm)				
		1	2	3	4	5
Farmer	0˚	2.418	1.169	0.641	0.44	0.355
	90˚	2.423	1.099	0.581	0.417	0.32
Semi flex	0˚	0.646	0.391	0.31	0.237	0.196
	90˚	0.593	0.365	0.29	0.208	0.145
Pinpoint	0˚	0.631	0.38	0.304	0.229	0.181
	90˚	0.569	0.346	0.277	0.19	0.127

Tab.3. Head leakage contribution (%) concerning isocenter dose for 6MV Beams with different chambers

Chamber	Collimator angle	Distance from field border(cm)				
		1	2	3	4	5
Farmer	0˚	0.003	0.003	0.003	0.003	0.003
	90˚	0.02	0.021	0.02	0.019	0.019
Semi flex	0˚	0.003	0.003	0.003	0.002	0.003
	90˚	0.034	0.033	0.032	0.029	0.028
Pinpoint	0˚	0.008	0.006	0.006	0.003	0.013
	90˚	0.028	0.028	0.025	0.025	0.028

Tab.4. Out-of-field dose in percentage concerning the isocenter dose for 3 cm²×3cm² field size for Varian Unique linear accelerator

Scatter component (%)	Distance from the field border(cm)				
	1	2	3	4	5
Phantom scatter	2.045	0.839	0.425	0.269	0.183
Collimator scatter	0.355	0.119	0.046	0.024	0.016
Collimator leakage	0.004	0.004	0.004	0.003	0.003

Tab.5. Out of field dose in percentage concerning the isocenter dose for 10 cm²×10 cm² field size for Varian Unique linear accelerator

Scatter component (%)	Distance from the field border(cm)				
	1	2	3	4	5
Phantom scatter	5.516	2.963	1.842	1.309	0.981
Collimator scatter	0.62	0.378	0.3	0.222	0.17
Collimator leakage	0.019	0.018	0.017	0.016	0.016

Tab.6. Out of field dose in percentage concerning the isocenter dose for 3 cm²x3 cm² field size for Varian True beam linear accelerator

Scatter component (%)	Distance from the field border(cm)				
	1	2	3	4	5
Phantom scatter	1.968	0.801	0.437	0.272	0.183
Collimator scatter	0.41	0.126	0.042	0.021	0.015
Collimator leakage	0.011	0.011	0.012	0.012	0.011

Tab.7. Out-of-field dose in percentage concerning the isocenter dose for 10 cm²×10 cm² field size for Varian Truebeam linear accelerator.

Scatter component (%)	Distance from the field border(cm)				
	1	2	3	4	5
Phantom scatter	4.775	2.703	1.776	1.256	0.919
Collimator scatter	1.566	0.809	0.495	0.369	0.293
Collimator leakage	0.012	0.012	0.012	0.013	0.012

Tab.8. TPS calculated scatter component (%) for Varian true beam

Field size (cm²)	Scatter component (%)	Distance from the field border(cm)				
		1	2	3	4	5
3x3	Phantom	1.947	0.73	0.487	0.243	0.243
	Collimator	0.608	0.243	0.122	0.122	0
10x10	Phantom	4.696	2.988	2.135	1.601	1.281
	Collimator	2.135	1.281	0.854	0.534	0.32

Tab.9. TPS calculated scatter component (%) for Varian Unique

Field size (cm²)	Scatter component (%)	Distance from the field border(cm)				
		1	2	3	4	5
3×3	Phantom	1.801	0.84	0.48	0.36	0.24
	Collimator	0.48	0.12	0.12	0	0
10×10	Phantom	4.348	2.757	1.909	1.379	1.167
	Collimator	1.591	0.954	0.636	0.424	0.212

collimator component, and leakage dose for VUP. All three components were measured with a collimator at 0° and 90° and verified, if any, for an intermediate field size of 10 cm² x 10 cm². Also, the same is observed for two different field sizes, 10 cm²×10 cm² and. A small field size of 3 cm²×3 cm² was measured for VTB, and VUP was measured with a semi-flex chamber. The contribution of these concerning isocenter dose was calculated and tabulated for both field sizes. The same measurements were performed in TPS with the scanned images of slab phantoms, and the dose was noted, and the out-of-field dose concerning the isocenter dose was calculated. TPS calculated out of filed dose is then compared with the ionization chamber measurements.

RESULTS

The individual scatters components (phantom scatter and collimator scatter and head leakage) of VUP were derived for different detectors and with different collimator orientations (0 Degree and 90 Degree) using equation 1 and then calculated the fractional dose in percentage concerning the isocenter dose and were tabulated in Table 1-3.

The percentage of phantom scatter, collimator scatter, and collimator leakage components for VUP and LINA-2 for 3 cm²×3 cm² and 10 cm²×10 cm² with collimator 0° were tabulated in Table 4 to Table 7.

The same procedure was performed in TPS with the scanned images of the slab phantom, and a fractional dose of phantom scatter and collimator scatter measured for both Linacs were tabulated in Table 8 and Table 9.

DISCUSSION

This study reveals that the phantom scatters contribution is high with the Semi flex chamber, collimator scatters with the Farmer chamber, and head leakage with the Pinpoint chamber. If we see the out-of-field dose relative to the central axis dose, near the edges -Semi flex showed the highest dose, whereas if we move away from the edges, all the chambers showed almost the same values. Abdallah et al. found that pinpoint showed a higher out-of-field dose when compared to Semi flex, whereas in this study, Semi flex showed a higher out-of-field dose near the edges [6]. The last dose was reported with a pinpoint chamber.

With the change in collimator angle, the out-of-field dose is high with collimator 90° compared to zero. This is following Abdalaal et al., who found that with the Semi flex chamber and with collimator 90, the out-of-field contribution was high, whereas, with the pinpoint chamber, the out-of-field dose was less for collimator 90 [6]. Analyzing individual components, the Phantom scatter shows higher for collimator 90 than zero for all chambers. The collimator scatter component was low with collimator 90 for all chambers, and head leakage increased with collimator 90° for all chambers.

It was also found that the phantom scatters, collimator scatters and collimator leakage contribution varies with field size. As field size increases, all these scatter components increase. When compared with the Varian True beam, Varian Unique showed a lower value of scattering factors. The same was observed with TPS calculated phantom scatter and collimator scatter contribution. The TPS showed zero leakage radiation. The ratio of TPS measured scatter factors with that of ionization chamber measured was calculated and it was found that TPS calculated phantom scatter variation from measured increases with distance from the field border (up to 40% within 5 cm) and a substantial variation was found in collimator scatter and head leakage. Huang et al. studied the out-of-field dose inaccuracies for IMRT in Pinnacle TPS and found a 30% variation near the field edge of 3 cm-4 cm and 100% far from the field edge [8]. They stated that the errors appear to be the underestimation of scattered doses from collimators and leakage radiation. R M Howell et al. measured the out-of-field dose in the range of 3.75 cm-11.25 cm from the field edge and found eclipse TPS underestimated the dose by an average of 40% ± 20% [9].

CONCLUSION

In this study, it was found that a higher out-of-field dose was observed with the Semi flex chamber compared with other ionization chambers. The influence of collimator rotation was also studied and found a slight increase in out-of-field dose with collimator 90 compared to zero. We found an increase in dose outside the field border with field size. Among the machines, VUP showed a lesser scatter factor compared to VTB. From TPS measurements, it was clear that more than phantom scatter, collimator scatter, and head leakage needs to be modeled separately to improve the accuracy of out-of-field dose in treatment planning systems.

CONFLICT OF INTERESTING

The authors have no conflict of interest to declare.

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ETHICAL PERMISSION

Ethical approval was not necessary for the preparation of this article as this study does not involve any human beings.

1. Kry SF, Bednarz B, Howell RM, Dauer L, Followill D, et al. AAPM TG 158: measurement and calculation of doses outside the treated volume from external-beam radiation therapy. Med phys. 2017;44:e391-429.
2. SIJI CT, Musthafa MM, GANAPATHI RR, ABDUL HK, Bhasi S. Out-of-field photon dosimetry study between 3-D conformal and intensity modulated radiation therapy in the management of prostate cancer. Int J Radiat Res. 2015; 13: 127-134.
3. Bordy JM, Bessieres I, d'Agostino E, Domingo C, d'Errico F, et al. Radiotherapy out-of-field dosimetry: Experimental and computational results for photons in a water tank. Radiation measurements. 2013; 57:29-34.
4. Abdelaal AM, Attalla EM, Elshemey WM. Dose estimation outside radiation field using Pinpoint and Semiflex ionization chamber detectors. Radiat Phy. Chem. 2017;139:120-125.
5. Abdelaal AM, Attalla EM, Elshemey WM. Estimation of out-of-field dose variation using markus ionization chamber detector. SciMed. J. 2020; 2:8-15.
6. Moghaddam FF, Bakhshandeh M, Ghorbani M, Mofid B. Assessing the out-of-field dose calculation accuracy by eclipse treatment planning system in sliding window IMRT of prostate cancer patients. Comput Biol Med. 2020; 127:104052.
7. Hirata M, Monzen H, Hanaoka K, Nishimura Y. Measurement of absorption dose outside irradiation field in IMRT. Radiat Prot Dosim. 2017; 176:425-433.
8. Huang JY, Followill DS, Wang XA, Kry SF. Accuracy and sources of error of out-of field dose calculations by a commercial treatment planning system for intensity-modulated radiation therapy treatments. J Appl Clin Med Phys. 2013;14:186-197.
9. Howell RM, Scarboro SB, Kry SF, Yaldo DZ. Accuracy of out-of-field dose calculations by a commercial treatment planning system. Phys Med Biol. 2010;55:6999.