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Measurements of peripheral dose for multileaf collimator based linear accelerator

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Background

In radiation therapy, peripheral dose (PD), or the dose outside the geometrical boundaries of the radiation field, is of clinical importance when anatomical structures such as foetus in pregnant women, gonads, and lenses of the eye, with low dose tolerances are involved. Even a small percentage of the total treatment dose might cause injury in such cases. The sources of peripheral dose are leakage from the treatment unit, scatter from the secondary collimators and beam modifiers such as wedges and blocks, and internal scatter originating in the patient

Aim

To determine the peripheral dose (PD) for multileaf collimator (MLC) based linear accelerator in water equivalent slab phantom for open and wedged fields.

Materials/Methods

PD measurements were carried out for 6 and 15MV photons using a 0.4cc parallel plate chamber in the slab phantom. Measurements were performed for different field sizes at different depths (D_{max} , 5cm and 10cm) and up to a maximum distance of 30cm beyond the field edges. PD was measured using wedge filters also. PD was further computed using a three-dimensional treatment planning system (3D TPS).

Results

For 6MV photon beams, the maximum PD for open beams at 5cm distance from the field edge was 3.42% and the minimum PD at 20cm distance was 0.11%. For 15MV, the maximum PD for open beam at 5cm distance was 3.07% and the minimum PD was 0.14%. For wedge filters, the maximum PD measured at 5cm distance for 6 and 15MV photons were 5.56% (60° Wedge) and 5.03% (45° wedge). The TPS PD values showed minimal variation from the measured values.

Conclusions

The PD due to MLC and beam modifiers would definitely be helpful to assess the doses received by the relevant critical structures outside the treatment field.

Key words

multileaf collimator • megavolt beams • peripheral dose • radiation dosimetry

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BACKGROUND

In radiation therapy, peripheral dose (PD), or the dose outside the geometrical boundaries of the radiation field, is of clinical importance when anatomical structures such as foetus in pregnant women, gonads, and lenses of the eye, with low dose tolerances are involved. Even a small percentage of the total treatment dose might cause injury in such cases. The sources of peripheral dose are leakage from the treatment unit, scatter from the secondary collimators and beam modifiers such as wedges and blocks, and internal scatter originating in the patient. Kase K.R. et al. [1] reported that machine scatter contributed 20–40% of the total secondary dose depending on machine, field size, and distance from the radiation field. Stovall M. et al. [2] explained in detail the techniques to estimate and reduce foetal dose and the biological effects of foetal irradiation with photon beams. Sasa Mutic and Eric E. Klen [3] observed the effects of peripheral dose distributions with tertiary multileaf collimation (MLC). They concluded that a strategic orientation of the collimator with a tertiary MLC could reduce PD distributions considerably. This decrease lessens the necessity of external lead shielding for reducing the critical organ dose. Our present work is concerned with estimation of peripheral dose from a linear accelerator (linac) equipped with MLC as secondary level collimation. Further, the effects of wedge filters on peripheral dose were investigated. The measured data were then compared with the treatment planning system values.

AIM

To determine the peripheral dose (PD) for multileaf collimator (MLC) based linear accelerator in water equivalent slab phantom for open and wedge fields.

MATERIALS AND METHODS

6 and 15MV photon beams produced by a high-energy linear accelerator (Siemens -Primus, Germany) equipped with in-built MLC replacing X-jaws were used for estimation of peripheral dose. The MLC consists of double focused tungsten leaves of 27 pairs, each projecting to 1cm width and 2 extreme pairs projecting to 6.5cm width both at isocentre. All leaves move along the cross-plane and perpendicular to the central axis. Measurements were taken using a 0.4cc plane parallel plate chamber (PPC-40, Scanditronix)

in a solid PMMA slab phantom (Scanditronix). The dimension of the each slab was $30 \times 30 \times 1 \text{ cm}^3$ ($l \times w \times h$). The phantom was set in such a way as to obtain the required dimension of $60 \times 30 \times 15 \text{ cm}^3$ ($L \times W \times H$). Great care was taken to ensure that there was no air gap while aligning the slabs. The chamber was connected to a calibrated electrometer (DOSE-I, Scanditronix). The reproducibility of the dosimeter system was checked and the coefficient of variation was found to be 0.011%. For each field size of 5×5 , 10×10 and $15 \times 15 \text{ cm}^2$, measurements were carried out at depths of D_{max} , 5cm and 10cm. The target to chamber distance (TCD) was maintained at 100cm throughout the measurements. The peripheral doses were measured at 0, 5, 10, 15, 20, 25 and 30cm distances from the geometric field edge. Each measurement was repeated five times and the mean value of the readings were noted. The standard deviation was found to be within ± 0.05 . All the measurements were taken for 100MU along the longitudinal axis of the machine with gantry and collimator angles both set at zero degree. The uncertainty due to positional accuracy was found to be within 5mm. The peripheral doses were also measured for the available wedge filters of 15° , 30° , 45° and 60° . All the data were normalized to central axis at depth of dose maximum. These measurements did not account for dose contributions from photoneutrons. As pointed out in the AAPM TG-36 report, the contribution of neutrons to the total PD is negligible or small near the beam edge for energies less than 10MV. At greater distances, the total PD is much smaller, but the fractional contribution from the photoneutrons can be high [4,2].

Also the slab phantom was imaged by a computerized tomography simulator (SOMATOM – emotion, Siemens) to obtain three dimensional (3D) image data sets of 3mm slices and transferred to the 3D treatment planning system (TPS- PLATO SUNRISE, NUCLETRON) through the lantis network. The peripheral doses were recorded from the TPS and compared with the measured values.

RESULTS

Figures 1A and 1B show the measured and TPS PD distribution for open and different wedge filters for a 10×10 field at 10cm depth for 6MV photons between 5cm to 30cm distance from the field edge. It is observed that a) PD decreases exponentially as the distance from field edge increases. For 6MV photon beams, the maximum PD

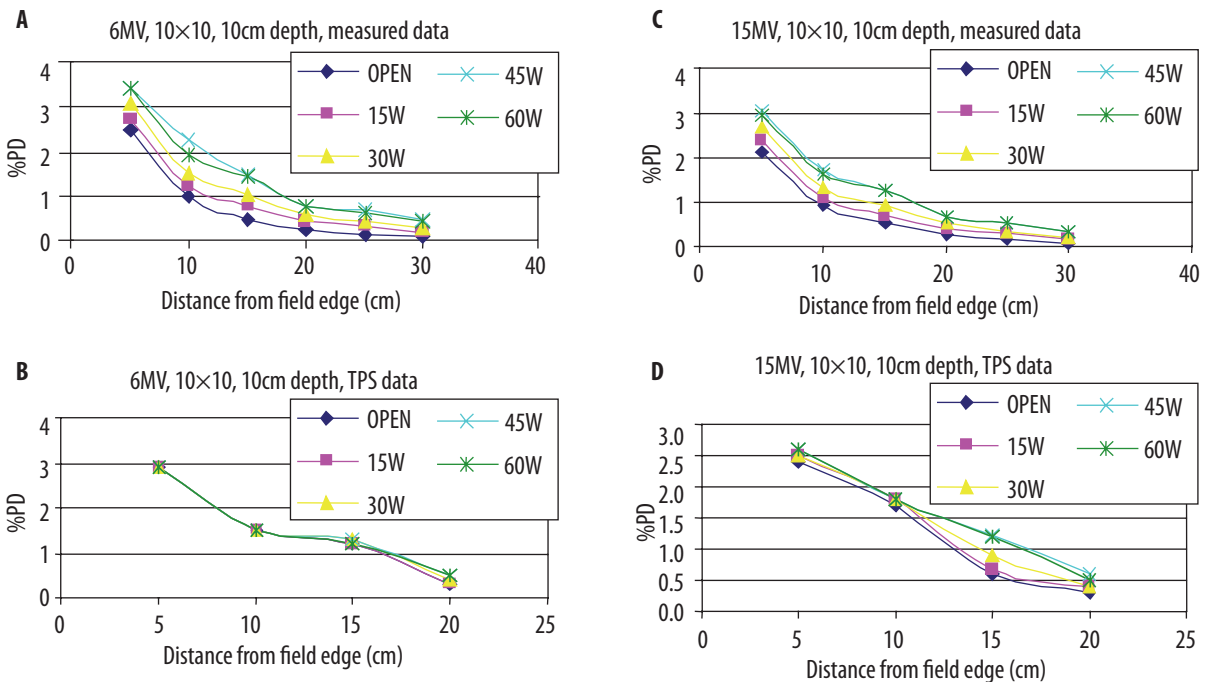


Figure 1. PD distributions for open and different wedge filters at 10cm depth for 10x10cm field size from (A) 6MV Measured, (B) 6MV TPS, (C) 15MV Measured, (D) 15MV TPS.

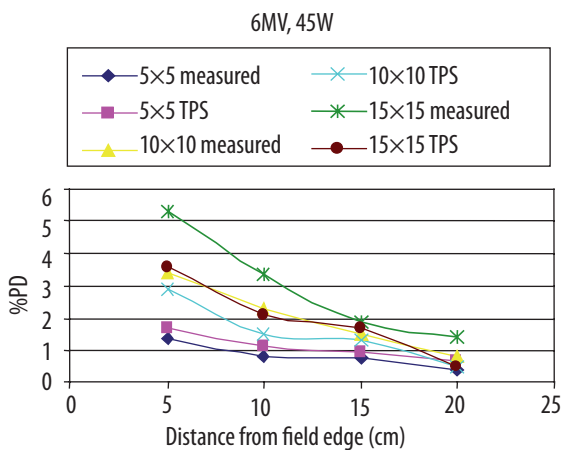


Figure 2. Comparison between measured and TPS PD distributions as a function of different field size at 10cm depths for 6MV photon with 45° wedge.

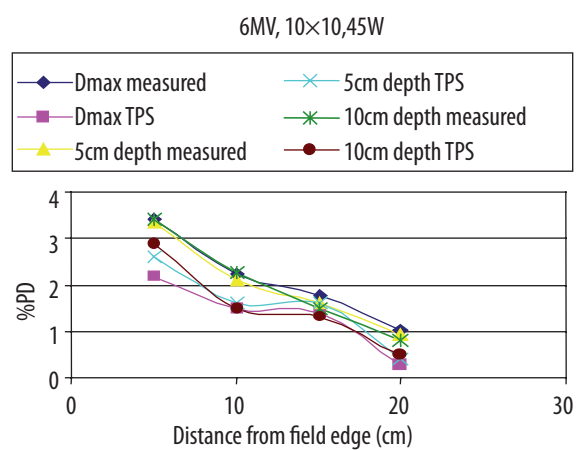


Figure 3. Comparison between measured and TPS PD distributions from 10x10cm field size as a function of different depths for 6MV photon with 45° wedge.

for open beams at 5cm distance from the field edge was 3.42% and the minimum PD at 20cm distance was 0.11%. For 15MV, the maximum PD for open beam at 5cm distance was 3.07% and the minimum PD was 0.14%. b) As the wedge angle increases, PD also increases for all the wedge filters except for 60° wedge. For wedge filters, the maximum PD measured at 5cm distance for 6 and 15MV photons were 5.56% (60°

Wedge) and 5.03% (45° wedge). The qualitative behaviour of measured and TPS PD distribution for 15MV photon shown in Figures 1C and 1D is similar to that of 6MV photon except that PD values are less when compared to 6MV. In addition, it was observed that beyond 20cm from the field edge, the TPS PD values are shown as zero for open and all the wedge filters for 6 and 15MV photons. When comparing TPS PD values

of individual wedges with measured data for 6MV and 15 MV photons, although the change in percentage PD with respect to the distance from the field edge does not strictly follow an exponential pattern, the TPS PD values are in close agreement with the measured values.

Figure 2 represents the percentage PD as a function of field sizes for measured and TPS at a depth of 10cm for 6MV photon with 45° wedge. As can be seen, PD increases with the increase in field size. This means that PD is dependent on field size. The variation with field size is significant only for small fields. The percentage difference between 5×5cm and 10×10cm is much larger than the difference between 10×10cm and 20×20cm fields. Figure 3 compares the measured and TPS PD for 10×10 field at different depths for 6MV photon with 45° wedge. There is a clear demarcation of decrease in percentage PD with respect to increase in depth for larger distances (say beyond 15cms) than at closer distance from the radiation field due to the slope of the PD curves. It is also observed that PD is dependent on energy. As energy increases, PD decreases.

DISCUSSION

The purpose of this study is to estimate the influence of wedge filters, field size, different depths, and energy on PD and to compare the values with TPS. Shirin Sherazi et al. reported that when wedge filters are added to the beam, four effects must be considered. First, the wedge becomes another source of scattered radiation, which depends on the field size and distance between the wedge and the patient, and adds to the dose outside the field. Secondly, at the same time, it may shield some of the radiation scattered from the collimators. Thirdly, it may change the spectral and angular distribution of radiation entering the water scatter. Finally, to deliver the same dose to the water as in an unfiltered beam, considerably more radiation is delivered to the point in the field where the wedge is located than would be delivered in the absence of the wedge. This means the scatter from the collimators is likely to increase. Scrimger et al. and Svensson et al. also reported that significant additional secondary radiation would be generated by wedge filters, blocks and compensators. These devices modify the primary and thus the patient generated scatter, but at the same time are themselves sources of scattered radiation [5,6] Robin L. Stern have measured PD for three different machine configurations on two different linear accelerators. In his study, PD was measured at two depths and two field sizes for 6 and 18MV photons from a linac with a MLC.

The MLC was configured both with leaves fully retracted and with leaves positioned at the field edges defined by secondary collimator jaws. Comparative measurements were also made for 6MV photons from a linac without MLC. Peripheral dose was determined as a percentage of central axis dose for the same energy, field size and depth using diode detectors in solid phantom material. He reported that the data for the 6MV without MLC agreed with those for the beam with MLC leaves retracted. For both the energies at all depths and distances from the field edge, configuring the MLC leaves at the edge yielded a reduction in peripheral dose of 6% to 50% compared to MLC leaves fully retracted [7]. Our measurements show that PD is dependent on wedge filters also. In our study, linac with MLC being secondary level collimation, an increase in peripheral dose ranging from 7.6% to 59.6% was observed with the use of wedge filters when compared with the open fields. Although there is a reduction of PD with the presence of MLC, it is necessary to assess PD when wedge filters are used along with MLC. Furthermore, our measured data using a parallel plate chamber are within the acceptable limit of accuracy of 3%. The uncertainty due to positional accuracy was found to be within 5mm. Peripheral doses are perhaps of greatest concern because of the risk of leukaemia associated with radiation exposure of the active bone marrow. The relationship between radiation dose and leukaemia is not entirely understood for low doses [8]. The calculation algorithm used in our treatment planning system has limitations in the calculations of PD at greater distances from the radiation field edge (say beyond 20cm). The pencil beam algorithm is used to estimate PD based on the equivalent path length method.

CONCLUSIONS

Our study concluded that the peripheral dose is a function of field size, depth and energy. The estimated PD due to MLC and beam modifiers such as wedge filters would definitely be helpful to assess the doses received by the relevant critical structures outside the treatment field. However, in some clinical situations it is required to use external shielding for critical organs such as testes, foetus etc. for further reduction of PD.

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