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Measurement of off-axis and peripheral skin dose using radiochromic film

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Abstract. A radiotheraphy skin dose profile can be obtained with radiochromic film. The central axis skin dose relative to D_{max} for a 10×10 cm^2 field size was found to be 22%, 17% and 15.5% for 6 MV, 10 MV and 18 MV photon beams. Peripheral dose increased with increasing field size. At 10 MV the skin dose 2 cm outside the geometric field edge was measured as 6%, 10% and 17% for 10×10 cm^2, 20×20 cm^2 and 30×30 cm^2 field sizes respectively. Off-axis skin dose decreased as distance increased from central axis for fields with Perspex block trays. For a 20×20 cm^2 field, an approximately 5–8% drop in percentage skin dose was observed from central axis to the beam edge.

1. Introduction

The epidermal and dermal layers of skin extend down to a depth of approximately 1 mm (Williams *et al* 1989). Measurement of off-axis and peripheral skin dose (Fraass and van de Geijn 1983, Kase *et al* 1983) with conventional detectors such as ionization chambers (Mellenberg 1995) becomes a tedious task as dose integration is required at each position, then the detector needs to be repositioned. The wide diameter of parallel plate ionization chambers also provides poor spatial resolution in regions such as the penumbra and other high dose gradient areas. Extrapolation TLDs (Kron *et al* 1993) provide better spatial resolution, but require batch calibration and provide only point by point data. Radiochromic film provides a complete surface dose profile data set limited only by the spatial resolution of the readout densitometer. This ensures very convenient collection of off-axis and peripheral skin doses in phantoms or *in vivo*. Radiochromic film's near water equivalence also reduces the possible perturbations caused by primary and backscatter fluence. This note reports off-axis and peripheral skin dose measurements achieved with radiochromic film.

2. Materials and methods

Measurements were performed with two Varian 2100C accelerators at photon energies of 6 MV, 10 MV and 18 MV. The film used was Gafchromic‖ MD55-2, batch number 970116.

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‖ ISP Technologies—Nuclear Associates.

The film results were corrected for non-uniformity with a double-exposure technique. The film was analysed with a 670 nm red GaAlAs ultrabright LED on a converted Scanditronix RFA300 densitometer (Carolan *et al* 1997). Results are compared with Attix ionization chamber results at 0.15 mm depth for skin dose analysis. The effective depth of measurement in MD55-2 was found to be 0.17 ± 0.03 mm water equivalent for high-energy photon measurements. The Gafchromic film was placed perpendicular to the beam path on the surface of a solid wafer slab phantom. The film was cut into 1 cm $\times$ 12 cm strips and used to cover the beam profile. For larger field sizes, two strips were used to extend into the peripheral region. Errors associated with MD55-2 radiochromic film are mainly due to inherent variations in the film thickness and optical defects caused by scratches, finger prints and similar marks. Combination of these errors produce a standard error of measurement of approximately $\pm 2\%$ (one standard deviation) of $D_{\max}$ for measured dose.

3. Results

Figure1(*a*) shows the percentage skin dose normalized to 100% at $D_{\max}$ measured using MD55-2 Gafchromic film placed on the surface of a solid water slab phantom at 6 MV photon energy. The 10×10 cm^2 field size and 30×30 cm^2 field size shown are open fields without any beam modifying devices. Skin dose is greater for the larger field sizes at central axis and at all points inside and outside the field. The 20×20 cm^2 field has a 6 mm Perspex block tray placed at 65.4 cm from the source. A 3 cm wide by 8 cm thick lead block is positioned on the block tray in an off-axis position. The Perspex block tray increases the skin dose and also produces a higher surface dose (approximately 7%) at the central axis compared with the field edge. Under the lead block, the skin dose reduces to approximately 20% of $D_{\max}$.

Figures 1(*b*) and 1(*c*) shows results for the experiment repeated for 10 MV and 18 MV photons. Results show that the reduction in skin dose under the block decreases as beam energy increases. Reductions in dose under the lead block are approximately $10\% \pm 2\%$ for 6 MV, $7\% \pm 2\%$ for 10 MV and $3\% \pm 2\%$ for 18 MV.

4. Discussion

The finite thickness of Gafchromic film influences the measurement of ‘skin’ dose to a certain depth, namely 0.17 ± 0.03 mm. The skin region which extends within the first 1 mm of depth has a large dose gradient with a change of up to 20% mm^{-1} occurring in this region. The measurement of 0.17 mm from the Gafchromic film is the minimum depth of measurement attainable with this dosimeter and relates to a region just below the basal cell layer which is located at approximately 0.1 mm depth.

The sites of electron contamination production are well known (Nilsson 1985, Biggs and Russell 1989, Butson *et al* 1996). This dose combined with backscatter radiation produces the skin dose profiles as measured by Gafchromic film.

The increase in percentage skin dose due to the Perspex block tray is greater at central axis with an approximate reduction of 5–10% from the central axis out to the field edge. This may be explained by the lateral scatter of electron contamination from the block tray contributing a larger dose at the field centre compared with the off-axis and peripheral regions. This effect is seen for 6 MV, 10 MV and 18 MV photons with the magnitude of dose decrease off-axis remaining similar.

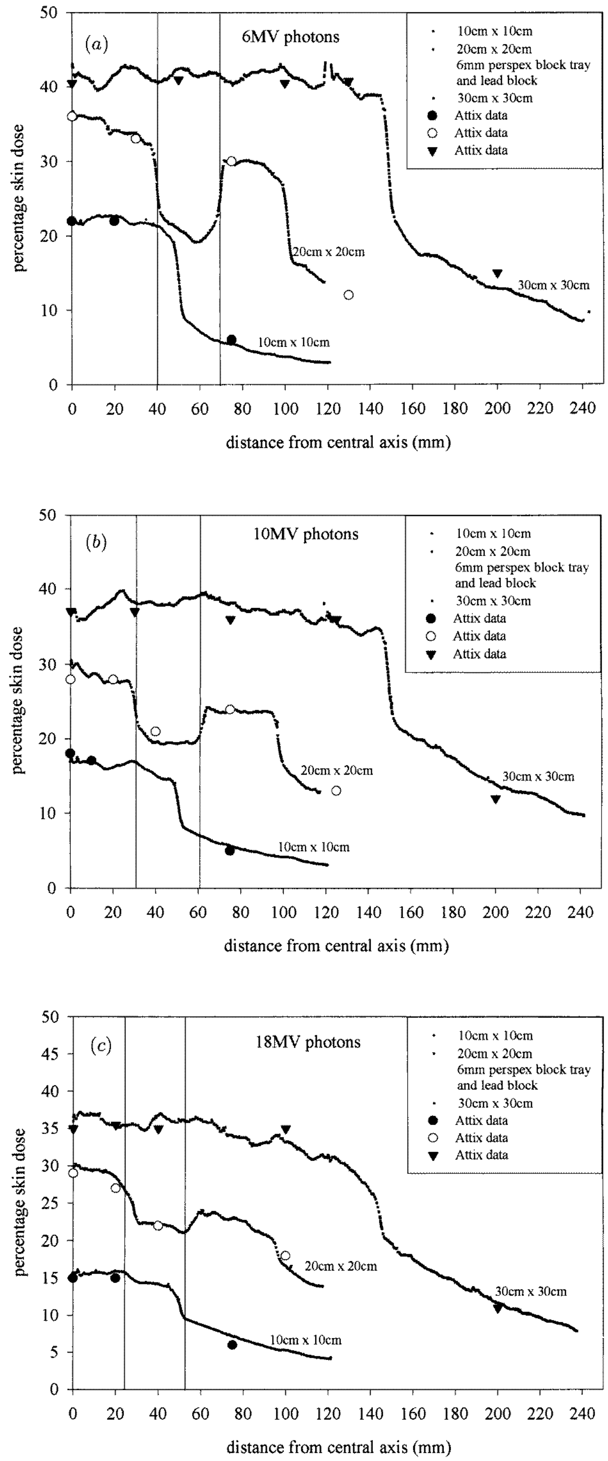

Figure 1. The off-axis and peripheral skin doses measured at (*a*) 6 MV, (*b*) 10 MV and (*c*) 18 MV photon energies. Several Attix chamber measurements made at 0.15 mm depth are shown to compare with Gafchromic results.

A reduction in skin dose is seen directly under a lead block as shown in figures 1(*a*), 1(*b*) and 1(*c*). This effect seems to be energy dependent, with a larger reduction in skin dose seen with lower energy. The block was thick enough to ensure that block transmission remained at less than 2% for all energies tested. The majority of dose deposited at the surface directly under the blocks therefore has been produced by electron contamination. Two important contributors to skin dose under blocks comes from the block tray and the air column. Nilsson (1985) and Yorke *et al* (1985) have shown that the air column has a much more significant effect on contamination at lower energies. This could explain the effect seen. By removing the photons in the air column directly under the blocks, we eliminate the production of electron contamination in this site. Thus a larger reduction in skin dose is seen at lower energies. For higher energies, the block tray produces the majority of electron contamination. As it is located approximately 35 cm from the skin, the electron contamination produced at this site has enough longitudinal distance to scatter producing the higher dose under the blocked region.

Peripheral skin dose increases with field size. Less than 1% of peripheral dose is due to collimator transmission and phantom scatter. Scattered electron contamination constitutes the rest of the percentage dose outside the field.

5. Conclusion

Gafchromic film shows potential as a very useful non-intrusive detector for the measurement of skin dose, especially in regions of high dose gradient such as the beam penumbra and under edges of blocks. Skin dose reductions under lead blocks are energy dependent with greater reductions seen at lower energy.

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