Extrapolated surface dose measurements with radiochromic film

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A radiochromic film extrapolation method is described for the measurement of surface dose from high energy photon beams. Extrapolated central axis entrance surface dose using Gafchromic film for a $10\times 10\,\text{cm}^2$ field size is $15\%\pm 2\%$ and $13\%\pm 2\%$ of D_{max} for 6 and 10 MV x rays, respectively. Extrapolated surface dose for a $30\times 30\,\text{cm}^2$ field with a 10 mm perspex block tray is 49% $\pm 2\%$ and $48\%\pm 2\%$ of D_{max} for 6 and 10 MV beams, respectively. All results agree with uncorrected Attix parallel plate ionization chamber surface ionization within 4% for the same beam energies and configurations.
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Key words: radiochromic film, Gafchromic, surface dose, extrapolation method

External photon beam surface dose has been measured using many techniques. Methods such as extrapolation chambers,[1] fixed parallel plate ionization chambers,[2–5] and (TLD) extrapolation[6] have successfully been used to measure surface dose. The original MD-55-1 Gafchromic film has also been used successfully to measure surface dose[7] due to its single layer design which allowed the active layer to be positioned at the surface. Design changes of the new, more sensitive MD-55-2 Gafchromic film which effectively produced a two piece MD-55-1 sandwich moved the two active layers away from the surface.[8] A simple extrapolation technique has been employed to estimate surface dose.

Measurements were performed with two Varian 2100C accelerators (Varian Pty Ltd, Milpitas, California) at photon energies of 6 and 10 MV. Field sizes ranging from $5\,\text{cm}\times 5\,\text{cm}$ up to $40\,\text{cm}\times 40\,\text{cm}$ were investigated. The film used was Gafchromic MD-55-2 (ISP Technologies Inc., 1361 Alps Rd., Wayne, NJ 07470) with batch number 970116. The film results were analyzed using a double exposure technique.[9] This is performed by giving each film an initial dose of 5 Gy and measuring optical density before experimental irradiation is performed. A variation of 3% for 1 standard deviation was recorded in optical density for the films used in the experiment due to nonuniformity in dose response.[10] The film was analyzed with a 670 nm, 3000 mcd, GaAlAs ultrabright light emitting diodes (LED) on a converted Scanditronix RFA300 densitometer.[11] Negligible polarization effects[8] were observed using this densitometer. A set of calibration films were irradiated to known doses in increments of 1 Gy to produce an optical density versus dose calibration curve. A third order polynomial function was used to produce this curve. Gafchromic film extrapolation surface dose results are compared to uncorrected Attix parallel plate ionization chamber results for surface ionization analysis. It has been calculated that the Attix chamber gives surface ionization accuracy within 1% using the Rawlinson[12] correction method. Both Attix chamber and Gafchromic film experiments were performed in a RMI $30\,\text{cm}\times 30\,\text{cm}^2$ solid water slab phantom at 100 cm source to surface distance.

The MD-55-2 Gafchromic film was tested for its thickness and physical density. The thickness was measured using digital calipers (Starrett) and was found to be 0.267 ± 0.005 mm. The films weight was measured using a micro balance (Mettler) and results were used to determine the physical density which was found to be $1.3\pm 0.5\,\text{mg/cm}^3$. Using these values an approximate effective water equivalent thickness of the Gafchromic film is calculated to be 0.35 ± 0.015 mm.

The extrapolation technique was performed by irradiating a stack of five horizontal films, $1\times 1\,\text{cm}^2$ pieces, placed on top of a solid water phantom. No scatter material was placed around the film during irradiation. In each case, the optical density was measured at the center of each film piece to minimize the effects of variations in measured dose near the edge of the film. The experiments and film analysis were performed at a constant temperature of $22\,^\circ\text{C}\pm 1\,^\circ\text{C}$ to reduce the effects of time and temperature dependent evolution[13,14] of Gafchromic film and the temperature dependent absorption spectra of the film. All optical density measurements were performed 24 h after irradiation. Gafchromic film was handled with tweezers to minimize scratching and fingerprints. The film is only removed from its light tight envelope during irradiation and readout to reduce the effects of ambient light.[15] All films were irradiated with an applied dose to

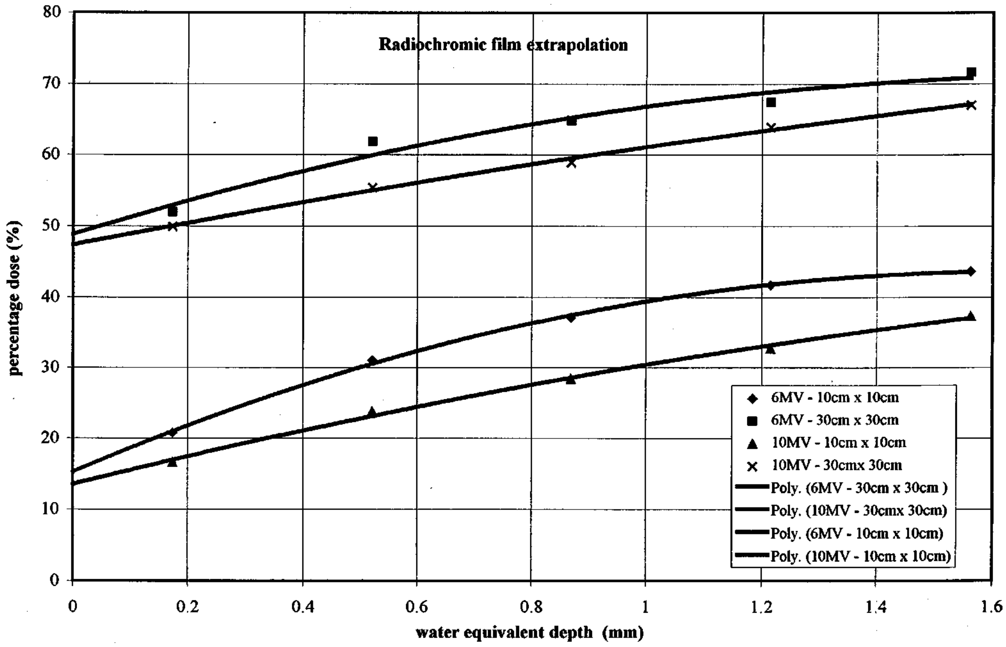

FIG. 1. A second order polynomial extrapolation is used to ascertain surface dose from Gafchromic film. Five films are placed in a stack to measure buildup dose within the first few millimeters.

D_{max} ranging from 40 to 80 Gy. The exact dose depended on the field size and was designed to give the film a surface dose of approximately 15–20 Gy.

Figure 1 shows the extrapolation technique used where five film layers are used to produce a central axis percentage build up dose measurement within the first few millimeters. Shown are results for $10\times10\,cm^2$ open field and $30\times30\,cm^2$ field size with a 10-mm-thick perspex block tray located at 65 cm from the source for 6 and 10 MV photons. The effective point of measurement was assumed to be at the

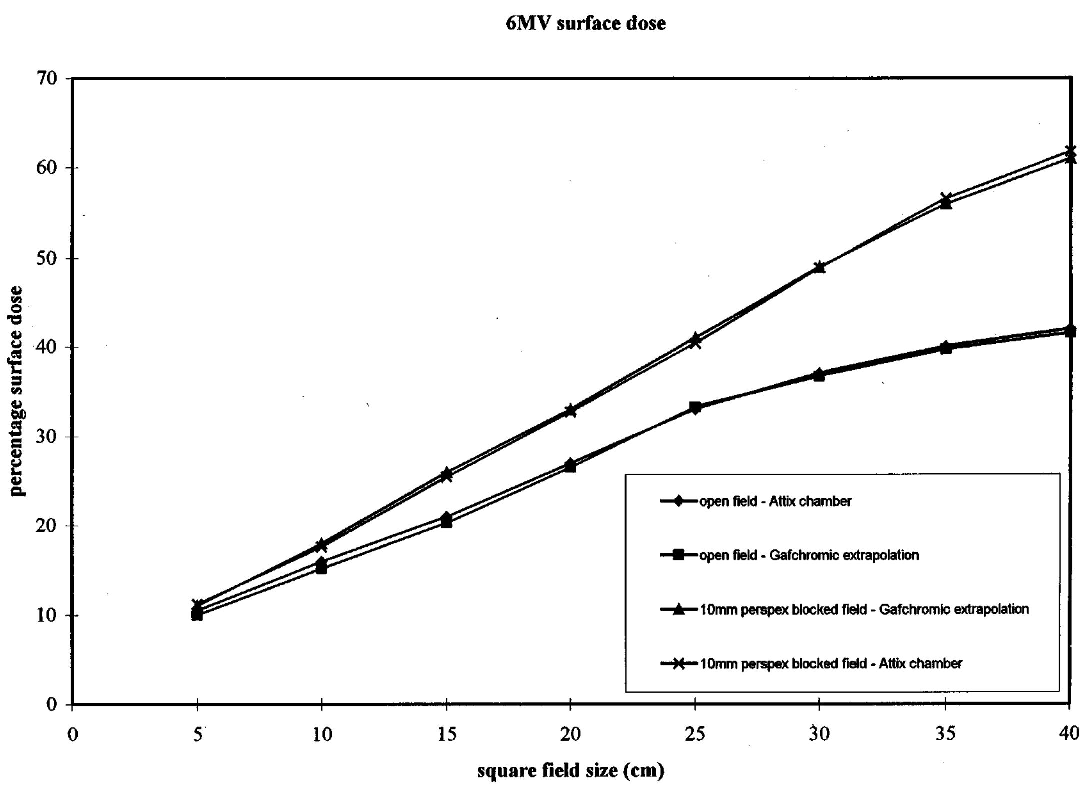

FIG. 2. Surface dose measurements comparing the extrapolation Gafchromic technique to uncorrected Attix chamber ionization results at 6 MV normalized to 100% at D_{max}. Results match using field sizes ranging from 5 up to 40 cm squares.

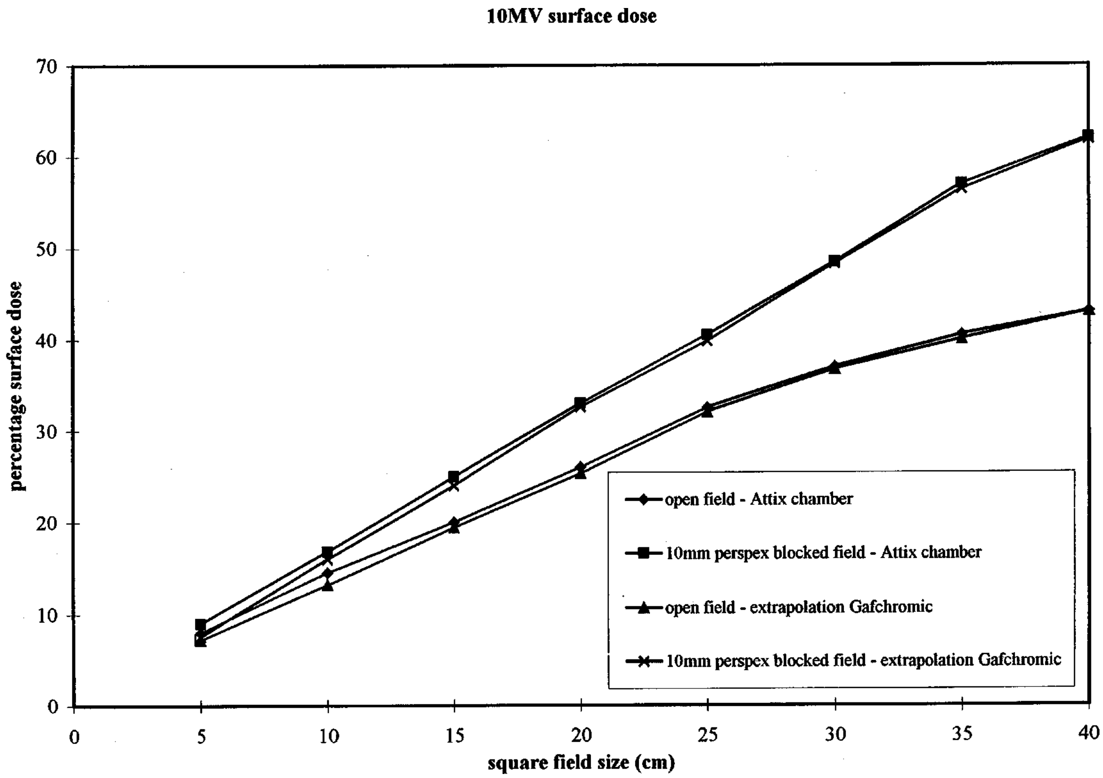

FIG. 3. Surface dose measurements comparing the extrapolation Gafchromic technique to conventional Attix chamber ionization results at 10 MV.

center of each film and thus the results for each film layer are quoted at half the water equivalent thickness, i.e., 0.175 mm. Dose was normalized to 100% at $D_{\max}$. Due to the nonlinear nature of photon build up characteristics,[2] a second order polynomial extrapolation was used as the line of best fit. Extrapolated surface dose for a $10\times10\,\mathrm{cm}^2$ field at 6 MV is $15\%\pm2\%$ of $D_{\max}$ compared to surface ionization of 16% $\pm1\%$ of $D_{\max}$ as measured by the uncorrected Attix chamber. The lack of side scatter may account for small deviations from Attix chamber results.

Gafchromic film and Attix chamber extrapolated surface dose measurements are compared in Fig. 2. These 6 MV data are plotted versus field size for blocked and open beams. Surface doses matched to within 2% over all field sizes and energies.

Figure 3 shows similar results for 10 MV photons with open and blocked fields. Gafchromic film and Attix chamber results agree within 2% of percentage surface dose. Gafchromic film extrapolation has produced an accurate surface dose assessment as well as produced dose measurements within the first 1 mm. Its present relatively low dose sensitivity excludes Gafchromic film from *in vivo* use for one fraction to assess entire treatment skin dose. However if replaced every day on a patient or left on a head cast a record of integrated skin dose could be kept. This could be compared with patient skin damage as assessed by some other method.[16] The necessary precautions needed to be taken to ensure the film is not damaged would include wrapping to prevent moisture or oil contamination, scratching and excess light exposure. Increased temperature during irradiation may also influence the dose response.

The method presented shows that Gafchromic film has a high spatial resolution for surface dose assessment and is a useful extrapolation device.

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