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NOTE

Surface dose extrapolation measurements with radiographic film

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Abstract

Assessment of surface dose delivered from radiotherapy x-ray beams for optimal results should be performed both inside and outside the prescribed treatment fields. An extrapolation technique can be used with radiographic film to perform surface dose assessment for open field high energy x-ray beams. This can produce an accurate two-dimensional map of surface dose if required. Results have shown that the surface percentage dose can be estimated within ±3% of parallel plate ionization chamber results with radiographic film using a series of film layers to produce an extrapolated result. Extrapolated percentage dose assessment for 10 cm, 20 cm and 30 cm square fields was estimated to be 15% ± 2%, 29% ± 3% and 38% ± 3% at the central axis and relatively uniform across the treatment field. The corresponding parallel plate ionization chamber measurements are 16%, 27% and 37%, respectively. Surface doses are also measured outside the treatment field which are mainly due to scattered electron contamination. To achieve this result, film calibration curves must be irradiated to similar x-ray field sizes as the experimental film to minimize quantitative variations in film optical density caused by varying x-ray spectrum with field size.

1. Introduction

Skin dose can vary quite considerably within the first few millimetres of depth due to the build up characteristics of x-ray beams (Zhu and Palta 1998, Nilsson and Brahme 1986, Harper *et al* 1991, Hounsell and Wilkinson 1999). The majority of these changes for entrance skin dose can be attributed to variations in electron contamination caused by parameters such as the field size variations whereby extra head scatter produced electrons can now be incident on the patient (Butson *et al* 1996). Assessment of skin dose is important for areas such as breast treatment where the outcome of cosmesis can be an important factor. Accurate measurement of skin surface dose is normally performed with detectors such as parallel plate ionization chambers. These devices, however, only produce point results and are time consuming to analyse a large area of dose delivery. Detectors such as radiochromic film (Butson *et al* 2003) can produce an accurate two-dimensional map of surface dose however, the cost of such film really precludes its use for large areas. Radiographic film is a relatively inexpensive alternative for two-dimensional surface dose assessment. Using an extrapolation technique whereby a series of stacked films are placed on top of one another, an estimate of surface dose could be performed over a large area at relatively low cost. This note investigates the accuracy and techniques required for accurate surface dose assessment using radiographic film.

2. Materials and methods

Kodak X-Omat V radiographic film was used for the assessment of surface dose measurement for high energy x-ray beams. To perform surface dose extrapolation, a series of three films were stacked on top of each other on the surface of a solid water phantom at 100 cm SSD. The films were in ready pack form which consists of the package envelope, paper separator and unexposed film. The stack of three films were then exposed to a 6 MV x-ray beam produced by a Varian 2100C linear accelerator in field sizes ranging from 10 cm × 10 cm up to 30 cm × 30 cm. For dose calibration, the calibration films were positioned in a solid water (Constanitinou *et al* 1982) phantom of dimensions 30 cm × 30 cm × 30 cm. The phantom was placed on a Varian 2100C linear accelerator treatment couch with the upper surface at the isocentre (100 cm). The film was positioned at a depth of D_{max}, 1.5 cm for 6 MV x-rays and doses ranging from 0 cGy to 60 cGy in 10 MU intervals were given with the film perpendicular to the central axis of the beam (Suchowerska *et al* 2001). Depending on the field size used for calibration, 10 Monitor units produces 10 cGy to 10.9 cGy. Various field size dose calibrations were performed ranging from 10 cm × 10 cm up to 30 cm × 30 cm to incorporate the effects of field size variation on radiographic film H and D curves. The film was processed in a Kodak M35 X-Omat processor in a single batch. The processed films were then analysed using a Vidar VXR-12 visible light densitometer and Scion imaging software. Surface dose assessment was performed using a dose extrapolation technique (Butson *et al* 1999) whereby an extrapolated surface dose was produced using a linear extrapolation to 0 cm effective depth of film using a relative effective depth of measurement for each radiographic film package. The relative depth of measurement for the radiographic film package was taken as the packages mid-point. This was found to be 0.38 mm ± 0.03 mm, water equivalent. Optical density to dose conversions were performed on the experimental films using results supplied from the calibration curves produced at the appropriate field size. Using a optical density calibration function of the Vidar scanner results form H and D curves produced calibration curves adequately fitted using a second order polynomial function over the dose range of 0 cGy to 60 cGy with an accuracy within 2 cGy. For comparison, photon beam measurements were also made using an Attix Model 449 parallel plate ionization chamber in a solid water stack phantom. The chamber was connected via a triaxial cable to a Keithley model 2540 electrometer at 300 V bias voltage. The Attix parallel plate ionization chamber is constructed primarily from solid water to closely approximate the interaction properties of water itself. The chamber window consists of a 0.025 mm thick, 4.8 mg cm^{-1} Kapton conductive film. The conducting surfaces are minimal thickness colloidal graphite. The air gap is 1 mm giving an ionization collecting volume of approximately 0.127 cm^3, which is vented, to atmosphere. Its over response due to sidewall scatter is less than 1% (Rawlinson 1992).

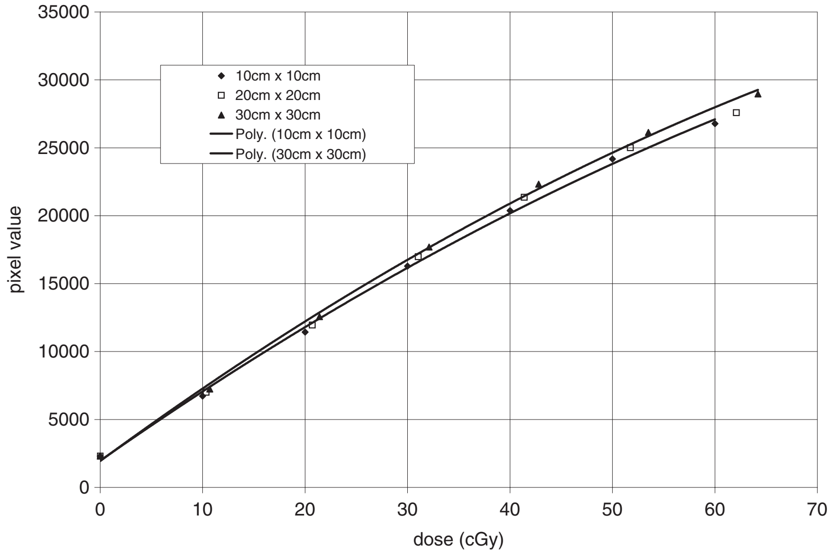

Figure 1. The calibration curves for radiographic film at different field sizes are shown. Changes are seen due to the variations in spectrum for various field sizes.

3. Results and discussion

Figure 1 shows results for calibration curves produced using various field sizes ranging from 10 cm × 10 cm up to 30 cm × 30 cm. As can be seen a variation in the optical density to dose relationship applies with larger field sizes producing a larger optical density to dose conversion. This is due to the increased low energy components of the x-ray spectra because of the changed energy spectra with field size and the energy-dependant ratio of the mass energy absorption coefficients of film to water. When surface dose analysis is performed, an appropriate calibration curve needs to be applied to perform the optimal calculation. This would entail using a matched field size or as similar as possible to minimize errors associated with x-ray spectral changes brought about by differing linac head configurations.

Figure 2 shows an example of dose profile curves produced using the three layers of radiographic film for a 30 cm × 30 cm 6 MV x-ray field. Results are quoted as percentage of maximum dose with the relative depths of measurement being 1.895 mm, 1.137 mm and 0.379 mm. As can be seen there is a relatively large increase in dose within the treatment field through the three layers of film as would be expected due to the x-ray build up characteristics of high energy x-ray beams. There would also be a contribution to dose from electron contamination in this region. In the peripheral dose regions we see a decrease in the measured percentage dose, which is associated with the attenuation of electron contamination through the film with a relatively small contribution to dose from scattered photons. Figure 3 shows a series of extrapolated surface dose profiles for several x-ray fields ranging in size from 10 cm × 10 cm up to 30 cm × 30 cm as a percentage of their relative $D_{\max}$ values. The error bars shown in the figure are a combination of errors associated with the film calibration method, variations of the data set and also associated with the nonlinearity in the depth dependence of build up dose. Also shown for comparison are measured point values for the Attix parallel plate ionization chamber measurements. Similar results have been found for higher energy x-ray beams such as 18 MV where the central axis extrapolated surface dose was measured

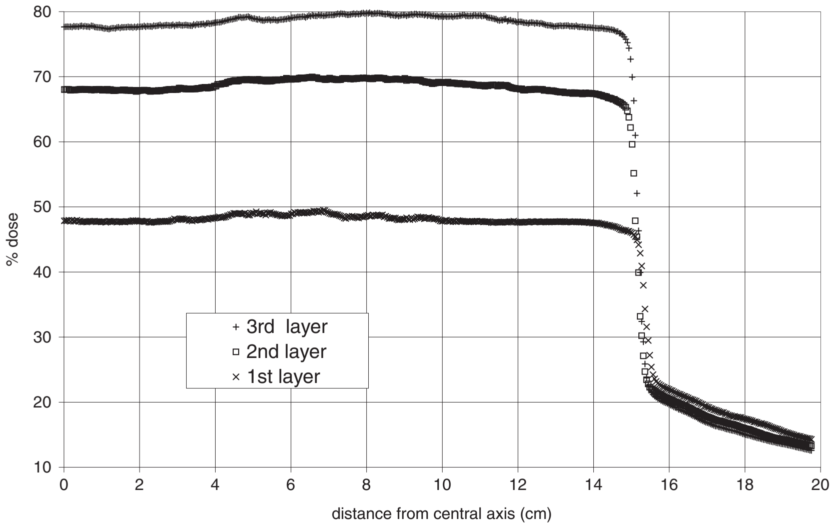

Figure 2. 'Skin dose' measured using the three layers of radiographic film for a 30 cm × 30 cm x-ray field is shown. Using these results an extrapolated surface dose estimate can be performed.

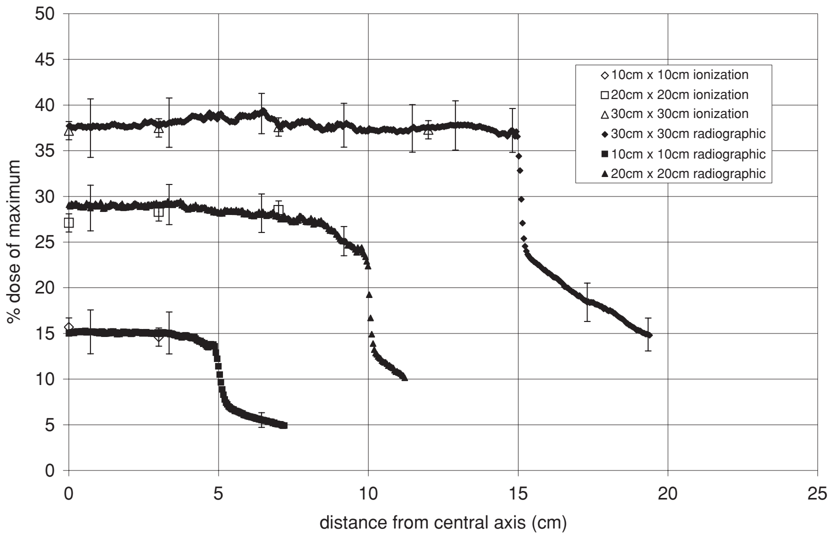

Figure 3. The extrapolated surface dose profiles for 6 Mv x-ray field sizes ranging from 10 cm to 40 cm squares are shown. Linear extrapolations are performed on data similar to that in figure 2 producing the profile. This method can easily be extended to two-dimensional areas.

to be 8% ± 3%, 14% ± 3% and 29% ± 3% for 5 cm × 5 cm, 10 cm × 10 cm and 20 cm × 20 cm field sizes, respectively. Results for the Attix chamber for the same field sizes were 7%, 12% and 27%, respectively. A linear dose extrapolation is performed from the three dose profiles obtained with the layered films at each specific point. It is acknowledged that a linear fit to extrapolation is only a first approximation of the dose build up at the surface due to the nonlinear nature of high energy dose build up characteristics. This approximation could lead to a slight overestimation in the extrapolated surface dose as the downward curvature of the build up curve is neglected. However, a nonlinear fit is not possible from only three data points. It is assumed though that the variation would be relatively small and within error limits of our measurements. To further improve the accuracy it may be necessary to increase the number of layers of film. Results show a relatively good agreement with ionization chamber measurements is possible as long as an appropriate calibration curve is applied. The main factor influencing the calibration curves was a field size dependence for radiographic film which is assumed to be associated with relatively large changes in the x-ray spectrum. Radiographic film response is relatively unaffected by electron contamination incident energy and as such, this technique could provide relatively accurate dosimetric data for surface dose assessment where the main contributor to dose is from electron contamination.

4. Conclusion

Radiographic film has been shown to measure surface doses using an extrapolation technique and matches parallel plate ionization data to within $\pm 3\%$ for open fields measured at 6 MV x-ray energy. Using this technique a two-dimensional dose map could be obtained both quickly and inexpensively for skin dose assessment.

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