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NOTE

Multilayer Gafchromic film detectors for breast skin dose determination *in vivo*

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Abstract

Assessment of skin dose delivered to patients from radiotherapy x-ray beams should be performed both inside and outside the prescribed treatment fields. A multilayer Gafchromic film detector which has high sensitivity for detection of radiation can be used to measure skin dose in a two-dimensional map over the skin surface if required. This is an advantage over other detectors, which only provide point dose estimates. A study of 25 patients undergoing breast irradiation was performed to analyse the ability of the multilayer detector to analyse skin dose and to assess both in-field and out-of-field radiation doses delivered during tangent field breast irradiation. Results show that the main contributor to total skin dose within the treatment field was delivered by exit dose. However, outside the field, most dose was delivered by entry beams. Patients with smaller breast separations where found, in general, to receive a higher total skin dose from entry and exiting beams at the central axis. Results also showed that a significant skin dose was delivered outside the treatment field and the main cause of this dose was from electron contamination from entry beams. The multilayer Gafchromic film detector provided adequate skin dose assessment within one fraction of treatment for *in vivo* results.

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. Skin dose can also vary considerably over the skin surface both within and outside the treatment field due to patient-specific set-up parameters. These changes can be attributed to variations in electron contamination caused by parameters such as the field size, the use of beam modifying devices such as blocking and compensators as well as factors involved with phantom scatter such as exit dose and beam angle of incidence

(Butson *et al* 1996, Zhu and Palta 1998, Huonsell Wilkinson 1999). It is, however, important to obtain knowledge of skin dose to identify areas where unwanted skin reaction could be expected or to make sure that structures at risk of recurrence (e.g. dermal lymphatics or drain holes) receive their prescribed dose. Devices such as TLDs, MOSFETs and diodes can all provide adequate estimates of point doses *in vivo*, at various effective depths on the skin structure. However, variations in skin dose across the skin surface both within and outside the treatment field can be high and a point dose may not provide adequate information for assessment of the treatment procedure. A multilayer Gafchromic film detector provides a high-sensitivity response, which can adequately measure skin doses at levels obtained from a single radiotherapy fraction (Cheung *et al* 2001). A simple and straightforward way to increase the dose response for a detector using Gafchromic film is to use a layered detector. Thus, using the principle described by the Beer–Lambert law (Pitt 1976) that the light absorbed by a medium varies exponentially with the path length of the light in the medium, we can effectively increase the change in optical density with absorbed dose by layering films together. This detector can also provide a two-dimensional map of dose if required or a dose profile across a region of interest. This note investigates the use of a multilayer device *in vivo*, specifically on a tangential breast irradiation technique to assess dose inside and outside of the treatment field. Inside the field is defined as the region within the diverging beam set by the geometric edge of the collimator jaws.

2. Materials and methods

Clinical measurements were performed on 25 patients undergoing breast irradiation using two opposed tangential fields of 6 MV x-ray energy. A Varian 2100C linear accelerator was used for treatment. All patients gave their informed consent to participate in the study. A patient received a prescribed dose of 200 cGy per fraction to the target volume for the entire breast excluding a 1 cm margin around the outside region. Most patients also have a prescribed supraclavicular field; however, measurements were not performed on this field area. The breast dose measured was delivered in two parallel and opposing tangential radiation fields, which were identical in size. A fixed SSD of 100 cm was used and for the majority of patients, wedges were used to improve the homogeneity of dose distribution. Point dose measurements were performed at the central axis of the entrance and exit positions of the two opposing beams. This was performed with the multilayer Gafchromic film detector. Profile measurements were made near the edges of the entrance and exiting beams on the medial and lateral sides of the breast with the multilayer Gafchromic film. Measurements were performed separately for entrance and exit doses as well as combined entrance/exit doses from the two opposing fields. *In vivo* measurements were performed five times on each patient during the treatment within the first week. Errors shown are one standard deviation in calculated dose over the five *in vivo* measurements. The multilayer detectors were correctly positioned onto the patient and held down with micropore tape during irradiation. This tape covered the edges of the detector and was sufficient in strength and flexibility to hold the detectors in position during treatment.

The multilayer Gafchromic film detectors were constructed from MD-55-2 Gafchromic film with batch number 970116. The higher sensitivity film dosimeters were constructed using five layers of MD-55-2 films placed in a stack and stuck together with tape. The film pieces were 1 cm $\times$ 12.5 cm in size. The tape only covered the outer 1 mm edges of each dosimeter. Care was taken to make sure that the stack was bound tightly together to minimize air gaps between film layers and to reduce the effects of reflected/scattered light within the film stack and to minimize movement of the separate film pieces. This was confirmed by measurements of the stack thicknesses compared to five individual layer thicknesses. Precautions in the

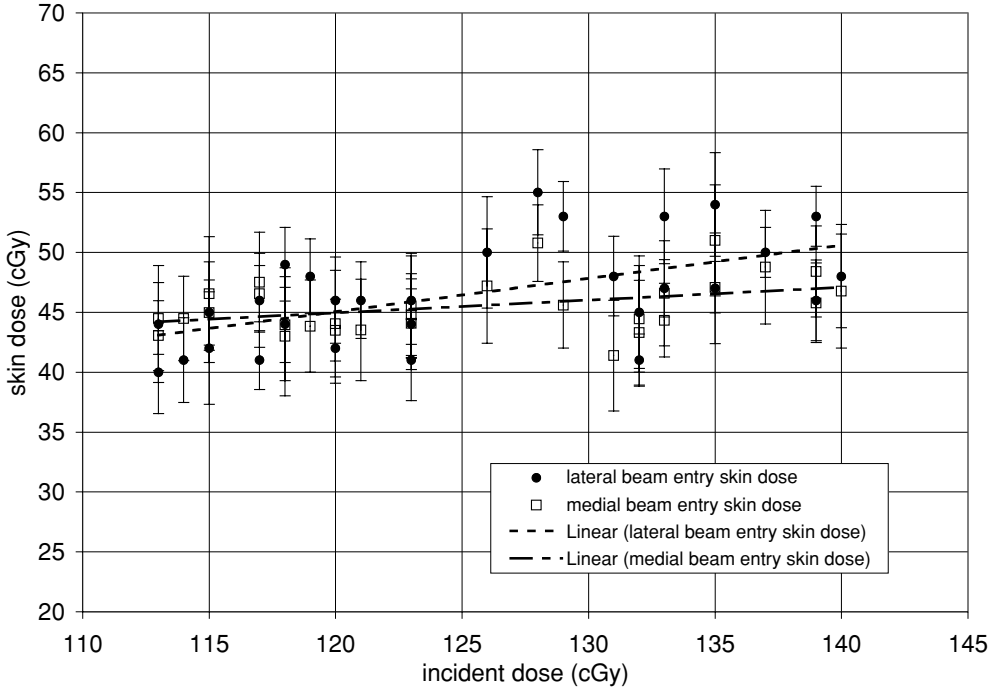

Figure 1. Entry beam skin dose measured *in vivo* for 6 MV x-ray beams measured with multilayer Gafchromic film over one fraction of treatment.

handling of radiochromic film outlined in TG-55 were used (Niroomand Rad *et al* 1998). The films during storage and film analysis were kept in temperatures of 22 ± 2 °C thus reducing the effects of time and temperature-dependent evolution and readout (Meigooni *et al* 1996) of the absorption spectra of the film. Films used *in vivo* on the patient would be subject to a temperature increase during exposure as they were placed on the patient's skin. TG-55 shows that a change in temperature from 20 °C to 35 °C during irradiation causes approximately a 2% increase in response when measured at 670 nm wavelength. No corrections to measured dose were applied due to this effect, as we could not accurately estimate the temperature of the film during experiments but it was assumed to be 35 °C or less. The film is only removed from a light tight envelope during irradiation and readout to reduce the effects of ambient light (Butson *et al* 1998). The film was calibrated using a double exposure technique where the optical density of the film detector is first recorded for no absorbed dose. Then a standard dose of 60 cGy was delivered and optical density over the entire film assessed for dose response. The film was initially assessed for background optical density (OD) which was then subtracted from results producing a net OD for irradiated doses. Variations in the background OD were found to be ±3% over the film pieces. Corrections were applied accordingly. Optical density was assessed using a 660 nm readout wavelength densitometer (Carolan *et al* 1997). *In vivo* measurements were then performed after this initial calibration.

3. Results and discussion

Figure 1 shows *in vivo* results for measured dose on the entry side of both medial and lateral beams from the 6 MV x-ray radiotherapy treatment. The *x*-axis represents the incident dose in cGy prescribed to allow a target volume dose of 200 cGy to be applied. The *y*-axis shows

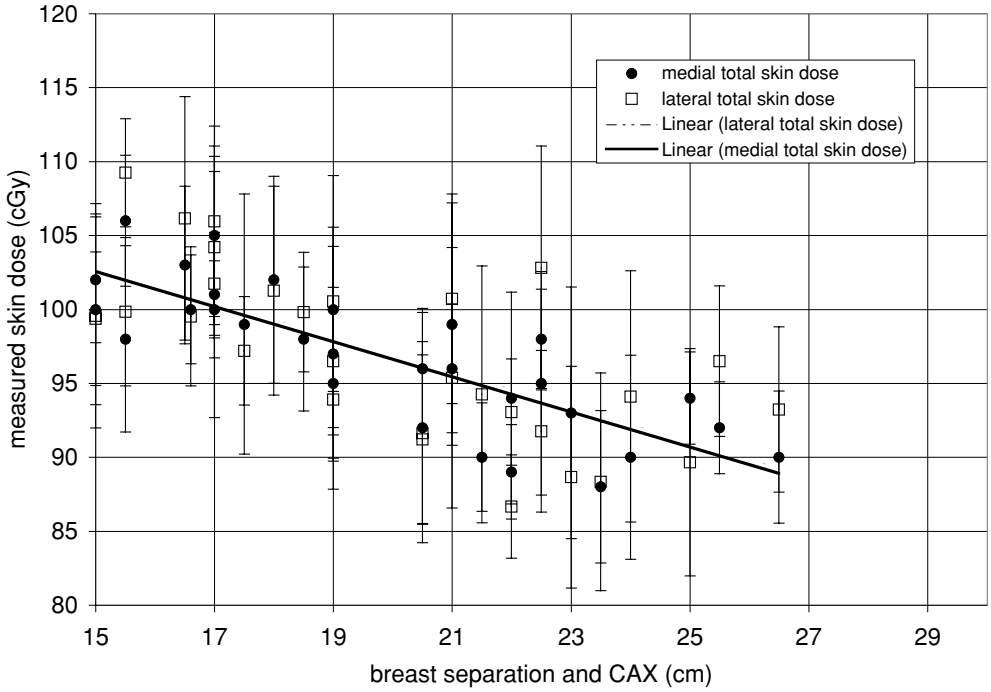

Figure 2. Total skin dose measured *in vivo* for 6 MV x-ray beams measured with the multilayer Gafchromic film over one fraction of treatment.

the measured cGy dose recorded on the multilayer film detector at the central axis of the x-ray beam. There is a slight general increase in measured skin dose with incident dose for both the medial and lateral fields as shown. By following the linear line of best fit results show that for the lateral beam, 44 cGy is absorbed at the skin depth for an incident dose of 115 cGy and 50 cGy is absorbed for 140 cGy incident. When quoted as a percentage of maximum dose, the skin dose delivered remains relatively constant along the line of best fit for the lateral beam and decreases slightly for the medial beam. That is, the percentage dose changes from approximately 38 to 36% of the maximum for the lateral beam and from 39 to 34% for the medial beam. The average relatively constant percentage dose recorded for the medial and lateral beams is recorded primarily due to the fact that for most patients' treatment, the field size and wedge configuration used remain relatively the same. Whether the patient has a small or larger breast the field size does not dramatically change. That is, the smallest field size used was a 7 cm $\times$ 15 cm field and the largest was a 12 cm $\times$ 20 cm field. The percentage of maximum surface dose on a flat phantom recorded for these two field sizes was 16 and 19% respectively. The angle of incidence for the medial beam was more dependent on the size of the breast compared to the lateral beam entry angle. That is, the smaller breasts had a larger angle of incidence at central axis compared to larger breasts. The size of the breast is directly associated with the incident dose (smaller breast, smaller incident dose). This may account for the slight increase in percentage dose of maximum for smaller incident doses where the angle of incidence would be larger.

Figure 2 shows results for total skin dose delivered from the combination of both beams as a function of breast separation at central axis. A definite trend is seen where the measured skin dose increases as the size of the breast decreases, i.e. breast separation decreases. This

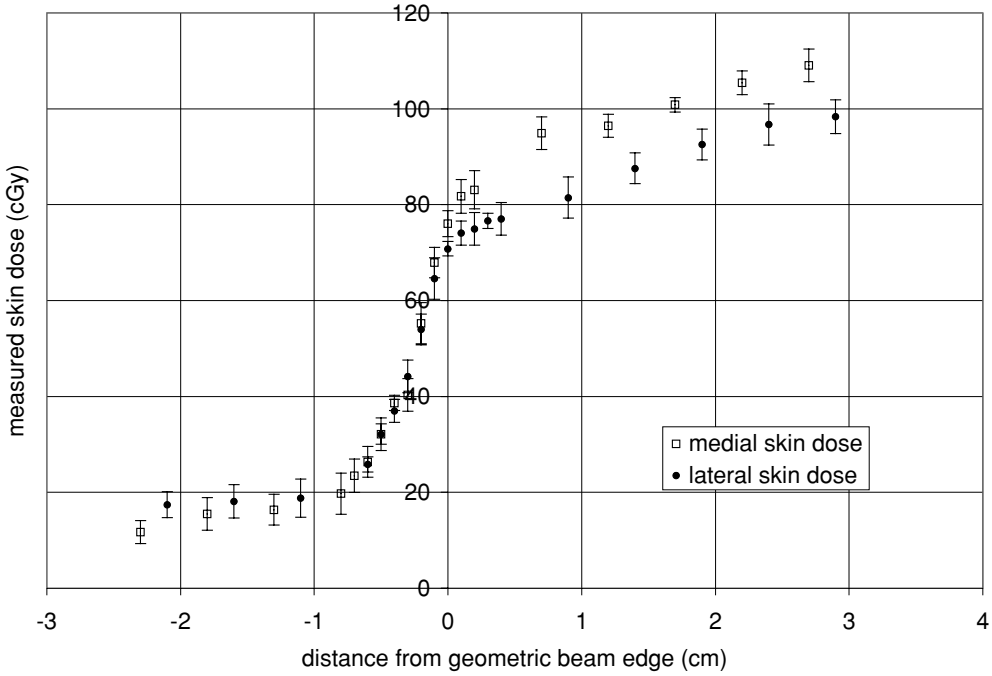

Figure 3. A profile of total skin dose measured near the medial and lateral beam edges for 6 MV x-rays.

can be directly attributed to a combination of the increased angle of incidence for entry beams and an increased exit dose associated with a smaller breast. Figure 3 shows typical profile measurements made on one patient using the multilayer film detector, at the beam edge from the medial and lateral sides. Results were collected over a 3-fraction period and calculated back to a single fraction as the dose recorded outside the treatment field was considered to be too low for a single fraction assessment. Results have shown that skin dose is present outside the field with up to 20 cGy per fraction measured, 2 cm away from the geometric beam edge for both the medial and lateral sides. Contributions to this dose come from electron contamination produced by the incident field, which is scattered outside the geometric field size and deposits dose near the surface, and from scattered exit dose from the opposing field. Figure 4 shows a breakdown of skin dose contributions from the entry beam and the exit beam as measured on the same patient on the medial side over a 5-fraction period but quoted as dose per fraction. As can be seen, the majority of skin dose delivered within the treatment field is due to exit dose from the opposing beam; however, dose outside the field is mainly due to electron contamination from the entry field. The dose deposited from the entry beam does not have a large variation in the 'penumbral' region and this is mainly caused by the fact that electron contamination is spread out and extends beyond the geometric field edge and the influence of phantom scatter is small at this depth. Results within the field for medial and lateral beams do show a difference in measured dose with skin dose delivered on the medial side producing a larger size than at the lateral beam edge. Again, this is directly attributed to the variations in dose delivered for varying angles of incidence. Due to the design of the treatment procedure, the medial beam angle of incidence would be larger than that for the lateral beam, especially near the inferior beam edge where measurements were

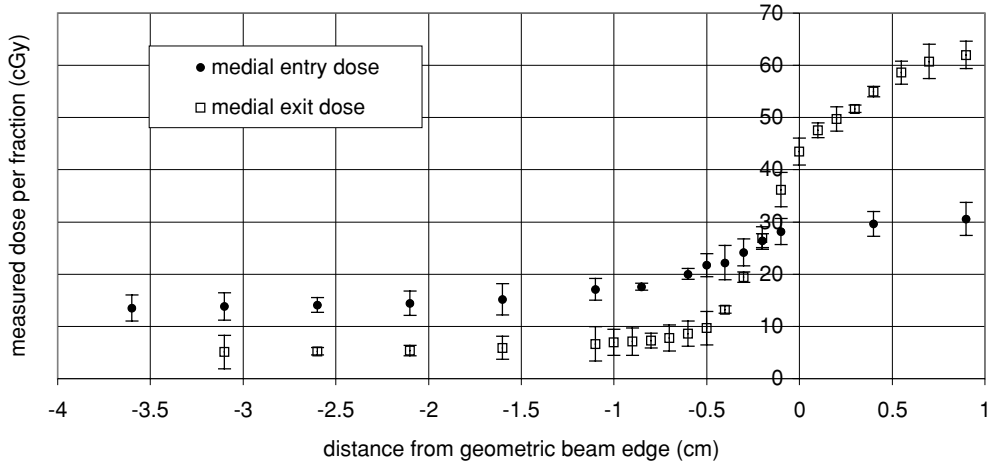

Figure 4. A profile of entry and exit skin dose measured on the medial beam edge for 6 MV x-rays.

taken. The increased dose delivered highlights the angle of incidence effect. The multilayer film produces adequate assessments of dose along a profile and can assess dose at multiple points both within and outside the field. These results have shown that a significant amount of dose is deposited in the skin region, outside the target volume/treatment field. Macklis *et al* (1999) have demonstrated that a mobile shield can be used to reduce scattered radiation on the contralateral breast. A similar technique could be used to minimize dose delivered to the skin outside the treatment field caused by scattered radiation and electron contamination.

4. Conclusion

The multilayer Gafchromic film detector has adequately measured skin dose during treatment for radiotherapy breast irradiation fields. It can provide information for point dose assessment or profile measurements of dose if required. The use of a mobile shield could reduce dose delivered to the skin outside the treatment field caused by scattered radiation and electron contamination.

Acknowledgments

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