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NOTE

Variations in skin dose associated with linac bed material at 6 MV x-ray energy

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Abstract

Treatment with radiotherapy x-rays at 6 MV energy produces a build-up effect whereby a smaller dose is delivered to the patient's skin compared to the tumour dose. With anterior fields, no material is normally placed over the patient's skin, thus providing the maximum skin sparing possible with the beam configuration used. A posterior beam normally passes through the treatment couch top and increases the dose delivered to the patient's skin. Both the Mylar sheeting and the support ribbing material produce a significant increase in skin dose. Measurements at 6 MV have shown that the basal cell layer dose can be increased by up to 51% of maximum dose with a carbon fibre/Mylar couch and by 28% for a tennis string/Mylar couch when compared to anterior beams. These values are associated with the position of the carbon fibre or tennis string ribbing. Dermal layer doses are increased by up to 30 and 24% of maximum dose for carbon fibre and tennis string, respectively. These values include a combination of dose due to the support ribbing and the Mylar sheeting. Due to the variability in patient positioning on the couch top, these increases would be spread out over the skin surface producing an average increase per unit area at the basal layer of up to 32 and 20% of the maximum, respectively, for carbon fibre and tennis string couch tops and 21 and 12% at the dermal layer compared to dose at D_{max}.

1. Introduction

When cancer patients are treated with radiation therapy beams, various skin reactions have been noticed. Early-stage effects include erythema and in some cases desquamation (Turesson 1989). Occasionally, late effects such as telangiectasis may occur. Doses delivered in the first millimetre of skin are often dominated by electron contamination and depend largely on

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beam set-up, field size and other patient-specific parameters. This is one of the prime reasons that measurements are necessary to estimate the build-up dose effects because this situation is not easily modelled by Monte Carlo-type calculations. Normally, a patient is treated either in supine or prone posture. If anterior and posterior beams are then used usually one of the beams must traverse through the linear accelerator treatment couch. The linear accelerator couch is normally made from carbon fibre or tennis strip material with a Mylar covering for comfort. The introduction of this material into the beam path increases the dose delivered to the patient's skin during treatment. This note examines the increases in dose delivered to the skin region.

2. Materials and methods

Measurements were performed on a Varian 2100C medical linear accelerator at 6 MV x-ray energy. Two types of linac couch inserts, a Varian carbon fibre couch insert and a Varian tennis string couch insert, were tested. The carbon fibre insert was constructed using a carbon fibre square ribbing, which had dimensions of 1.8 cm^2 with the ribbing being 2 mm wide and 3 mm thick. A 0.62 mm thick Mylar sheet was placed over the ribbing patient comfort. The tennis string insert was constructed from a square woven pattern of tennis string material. The tennis string was approximately circular in shape and its diameter was 1 mm. The square pattern was 1.4 cm in size. A 0.4 mm thick Mylar sheet was placed over the tennis string ribbing patient comfort. Measurements were made to calculate the increase in skin dose caused by the couch tops.

The dosimeter used for analysis was Gafchromic MD-55-2 radiochromic film with batch number 970116. Following the AAPM TG-55 (Niroomand-Rad *et al* 1998) recommendations, appropriate precautions in handling, calibration and scanning of the radiochromic film were taken. The film results were analysed using a double exposure technique (Zhu *et al* 1997). This is performed by giving each film an initial dose of 5 Gy to ascertain if any corrections were needed due to non-uniformity in dose response (Meigooni *et al* 1996). A non-uniformity of $\pm 3\%$ (2SD of the mean) was recorded in the optical density for the films used in the experiment and corrections were applied accordingly. The film was analysed with a 660 nm, 3000 milliCandela, GaAlAs ultra-bright LED that had been used to modify a Scanditronix RFA300 densitometer (Carolan *et al* 1997) to read in the red wavelength region. Negligible polarization effects (Klassen *et al* 1997) were observed using this densitometer. The film was left for a period of 24 h before optical density measurements were performed to reduce the effects of post-irradiation colouration (McLaughlin *et al* 1991). The effective depth of measurement in MD55-2 is 0.17 ± 0.03 mm water equivalent (Butson *et al* 1998). The Gafchromic film was handled using soft gloves to avoid fingerprints and other contaminants, which affect readout and a paper tab was placed on the side of the film with sticky tape, so it could be easily handled without touching the film. The Gafchromic film is prone to scratching which can also affect the optical density of readout. Care should be taken not to slide the film on surfaces with any force. The Gafchromic film was positioned directly on top of the treatment couch inserts and also at 1 mm depth in solid water (Constantinou 1982). Solid water (15 cm) was then placed over the Gafchromic film for backscatter material. The linac beam was directed through the linac couch material, perpendicular to it. Experiments were performed with field sizes ranging from 10 cm $\times$ 10 cm up to 40 cm $\times$ 40 cm at 100 cm SSD and skin dose profiles across the couch material were investigated. Most values for percentage dose are the values normalized to Dmax values. They are calculated by comparison of the optical density measurements made with the film dose to standard dose at Dmax to the values at skin depth. Open field measurements (where no couch material was present and relates to a

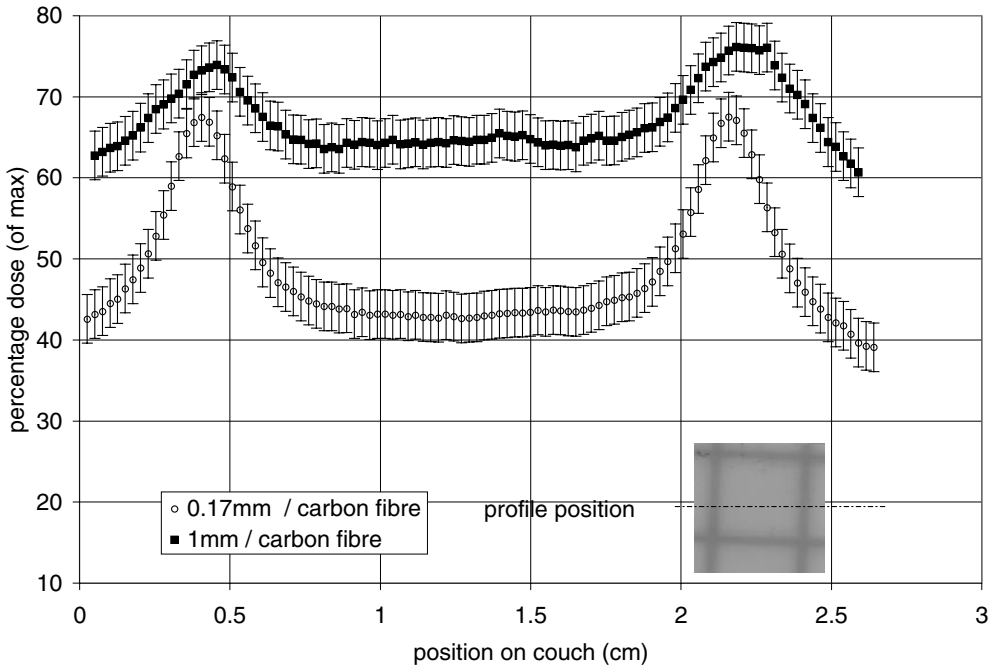

Figure 1. Percentage dose (of D_{max}) profile for skin dose delivered through a Varian carbon fibre/Mylar treatment couch. The carbon fibre ribbing increases skin dose dramatically as shown by the peaks in dose. The Mylar thickness is 0.62 mm. The image of the Gafchromic film shows the dose delivered to the depth of 0.17 mm and the position of the profile measurement shown. The image is not to scale.

patient's anterior beam configuration) were also performed with the same field sizes and beam configurations for comparison.

3. Results and discussion

Figure 1 shows a profile curve at approximately the basal cell layer (0.17 mm) and at the lower dermal layer depths (1.17 mm) for a 10 cm $\times$ 10 cm field size across the carbon fibre couch insert. It should be noted that the basal cell layer is located at approximately 2–10 mg cm^{-2} (Williams *et al* 1989) which is closer to the surface than our effective point of measurement, however, the values recorded are a close approximation to the basal layer dose. The dermal layer is located from approximately 0.1 to 1 mm depth depending on the site and thus the measurement at 1.17 mm is at the deeper edge of the dermal layer. Also shown on the figure is the image of the MD-55-2 film, which is located at the basal cell layer depth for the carbon fibre couch insert. The image shows the 'cross' pattern in the dose where the dark lines represent higher dose levels and are related to the position of the couch ribbing. The dotted line shows the position of the profile measurement taken. Percentage dose results on the profiles show a large increase in basal layer dose near the ribbing of the carbon fibre. This dose increases to 67% of maximum dose and falls to approximately 44% of the maximum outside this region. Both of these values are larger than the open field (or anterior beam) basal cell layer percentage of maximum dose (20%). The supporting Mylar sheet located on top of the carbon fibre insert causes the increase over the entire region and the carbon fibre ribbing causes the peak in the

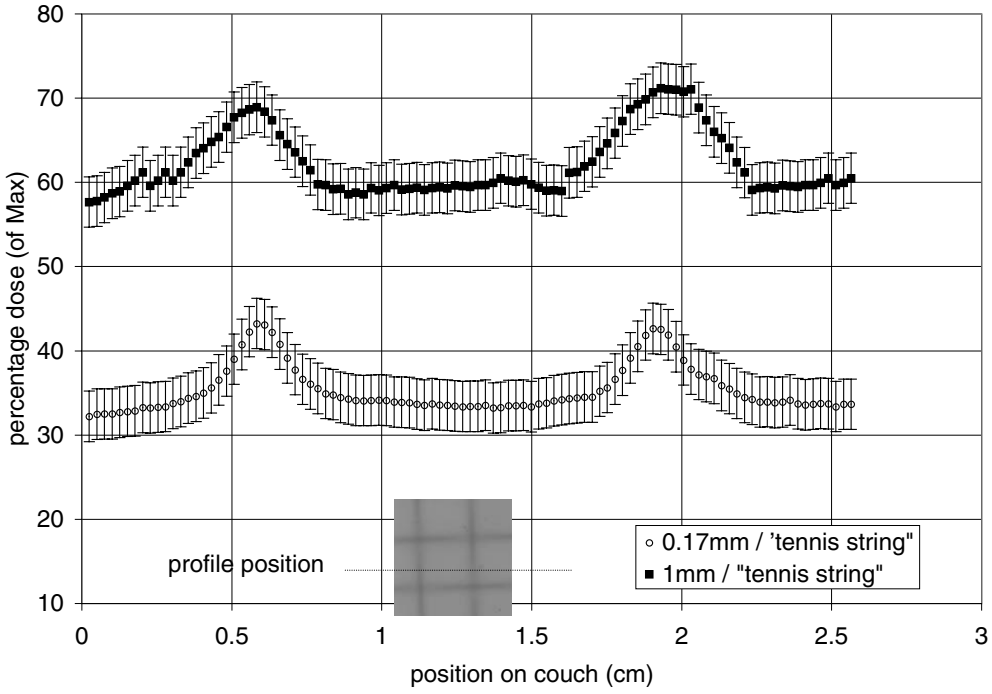

Figure 2. Percentage dose (of D_{max}) profile for skin dose delivered through a Varian, tennis string/Mylar treatment couch. Increases in skin dose are seen above open fields; however, the effect is not as large as for the carbon fibre couch. The Mylar thickness is 0.4 mm. The image of the Gafchromic film shows the dose delivered to the depth of 0.17 mm and the position of the profile measurement shown. The image is not to scale.

dose. The Mylar sheet, which is 0.62 mm thick, is used for support and comfort of the patient during treatment. The large peaks seen in the dose for the basal layer might be of concern, if the position of the patient on the couch was replicated exactly during every fraction of treatment. However, in a normal clinical situation the position of these peaks in skin dose would be spread over the skin region during the fractionated treatment. The average basal layer dose can be calculated by integrating the dose over the entire region within the field size used. This produces an average basal layer dose of 48% for the carbon fibre insert. The dose at the dermal layer also shows a peak over the carbon fibre insert, however, the magnitude compared to the rest of the dose in the field is not as large. The peak dose was measured as 73%. The average dermal dose calculated by integrating over the entire region was found to be 66%.

Figure 2 shows similar results but for a 'tennis string' couch insert. The Mylar sheet used on this couch top was measured as 0.40 mm thick. This is thinner than that used on the carbon fibre couch top. This would account for the difference in the basal layer and dermal layer skin doses under the supportive material. Again, the peaks in the dose are located directly under the tennis string material with a basal layer peak dose of 43%, with an average dose of 35% and a peak dose of 69% and average of 61%. The tennis string material is smaller in size and thinner than the carbon fibre top. Table 1 summarizes peak doses and average doses for various field sizes at the basal cell layer for the carbon fibre and tennis string couch inserts. As expected the doses increase with field size, however, the relative differences between the peaks and the

Table 1. Table of peak dose and average dose (of maximum) delivered to the basal layer.

Field size	Peak dose (% of D_{max})	Average dose (% of D_{max})	Open field/anterior beam (% of D_{max})
Carbon fibre/Mylar couch			
10 cm × 10 cm	67	48	16
20 cm × 20 cm	70	54	27
30 cm × 30 cm	72	58	37
40 cm × 40 cm	74	61	42
Tennis string/Mylar couch			
10 cm × 10 cm	43	35	16
20 cm × 20 cm	49	41	27
30 cm × 30 cm	53	44	37
40 cm × 40 cm	55	46.5	42

average dose are diminished. This is caused by the influence of electron contamination on dose in this region, which is a more predominant factor of influence at larger field sizes.

When comparing skin doses delivered with the use of two different couch tops, two major factors influence the results. First, the thickness of the Mylar sheet significantly affects the increase in dose over the entire region as would be expected with the introduction of a build-up material into the beams path. A recommendation would be to measure the thickness of the Mylar sheeting on the linac couch insert and replace it with a thinner sheet if skin doses were deemed to be a problem. Second, the carbon fibre insert produced a larger increase in skin dose than the tennis string material. This may be of concern when a patient is positioned in exactly the same position on the couch every time; however, clinically there is a very low probability of this happening. The carbon fibre ribbing covers approximately 23% of the surface area and the tennis string covers approximately 15% of the surface area. Thus the size of the peaks would be effectively reduced to approximately one-fourth and one-sixth of their original sizes on average for the carbon fibre and tennis string couches, respectively.

4. Conclusion

The couch top material, Mylar, carbon fibre or 'tennis string' increases the skin dose delivered to a patient when treatment occurs through it. Large increases are seen with the carbon fibre ribbing; however, due to day-to-day patient positioning, the relative increase in one region would be substantially diminished. Radiochromic film provided high-resolution detection in the measurement of dose from the linac couch materials.

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