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# Effects on skin dose from unwanted air gaps under bolus in photon beam radiotherapy

Martin J. Butson[a, b,*], Tsang Cheung[a], Peter Yu[a], Peter Metcalfe[b]

[a]Department of Physics, City University of Hong Kong, Kowloon Tong, Hong Kong

[b]Illawarra Cancer Care Centre, Department of Radiotherapy, PO Box 1798, Wollongong, NSW 2500, Australia

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**Abstract**

The dose under small air gaps located under bolus material of up to 10 mm have been measured with an Attix parallel plate ionization chamber and radiochromic film. For a 6 MV x-ray beam with 10 mm bolus, an air gap of 2 mm produced no reduction in skin dose when measured with the Attix chamber. An air gap of 4 mm will introduce a reduction of dose to the basal layer of approximately 0–4% depending on field size, angle of incidence and other patient specific parameters and a reduction of up to 10% could be seen at the basal cell layer for a 10 mm air gap. The 10% reduction was for a small x-ray field at 60 degrees angle of incidence and was a reduction in dose from 100% of $D_{max}$ down to 90% of $D_{max}$. Results at oblique angles of incidence show that larger reductions in dose are seen with increasing angle of incidence. Radiochromic film results agree with the Attix chamber results measuring 2% $\pm$ 2% decrease for a 4 mm gap and 4% $\pm$ 2% for a 10 mm gap at normal incidence. Clinically, results show that small air gaps can reduce skin dose, however, at least 90% of maximum dose is still delivered for air gaps up to 10 mm. 

*Keywords:* Skin dose; Bolus; Build up effect; Near surface tumor; Air gaps

## 1. Introduction

Megavoltage photon beams exhibit a dose build up effect (Khan 1984; Metcalfe et al., 1997). The absorbed dose is maximum at a certain depth beyond the surface. This produces a 'skin sparing' effect which is highly dependent on beam parameters such as energy, field size use of beam modifying devices and source surface distance (SSD). Most treatments are performed with megavoltage beams because deep tumors are effectively dosed whilst skin dose is low. To alleviate the risk of near surface recurrence, surface dose can be increased by build up materials (bolus) placed on the skin (Pointon (1991)). This is often the case for tangential treatment of the breast where dermal lymphatics can be sites of recurrence.

In some instances, due to the malleability of the bolus material, small air gaps of the order of a few millimeters might occur in certain regions of the treatment field. This report discusses whether these air gaps compromise the dose delivered to the skin and subcutaneous region during radiotherapy for normally and obliquely incident beams. The skin has two main layers, the epidermis and the dermis. The depth to the basal layer from the surface can vary in different parts

* Corresponding author. Tel.: +61-2-422-25709; fax: +61-2-422-65397.

*E-mail address:* mbutson@usa.net (M.J. Butson).

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of the body. The average depth is approximately 0.07 mm, Williams et al. (1989). The dermis which contains blood capillaries, sweat glands, sebaceous glands, nerve endings, hair follicles and dermal lymphatics extends down to between 1 and 4 mm.

## 2. Methods

Measurements were performed with a Varian 2100C linear accelerator at 6 MV x-ray energy as normally used in breast treatments at our center. Photon beam measurements were made using an Attix Model 449 parallel plate ionization chamber, in a solid water, Constanitinou et al. (1982) stack phantom and with MD-55-2 Gafchromic film. The solid water phantom consisted of slices ranging in thickness from 1 mm up to 5 cm. The Attix chamber was connected via a triaxial cable to a Keithley model 2540 electrometer at +300 V bias voltage. The Attix chamber was held in the phantom by a solid water slab designed to fit around it without introducing any air gaps. Gafchromic film was placed directly on top of solid water slices or sandwiched in between the slices to measure at depth. Recommendations outlined by TG-55, Niroomand-Rad et al. (1998) were observed and used when handling and calibrating Gafchromic film, using a double exposure technique. Results were obtained with varying field size and air gaps. The bolus materials investigated were wax and Med-tec bolus. The air gaps were introduced by placing small plastic blocks on the edge of the solid water phantom and placing the bolus on top of it. Measurements were performed with the source to top of solid water phantom distance being 100 cm as is the case for clinical treatment of breast tangentials at the Illawarra Cancer Care Centre. Results for wax and Med-tec bolus were found to be the same within measurement errors for all cases. Thus, results are quoted just as bolus material. Experiments were performed with the beam entering perpendicular to the phantom and at oblique incidence up to 60 degrees angle of incidence.

## 3. Results

Fig. 1 shows a typical build up curve for a 6 MV x-ray beam at 100 cm SSD for 0 degrees angle of incidence. Two field sizes are shown, 8 × 8 cm and 10 × 20 cm. Surface doses are 14% and 21%, respectively, for the two beams without bolus material. When 10 mm of bolus is placed on top of the phantom the 'surface' dose increases to 98% and 99%, respectively, for the beams as measured with the Attix

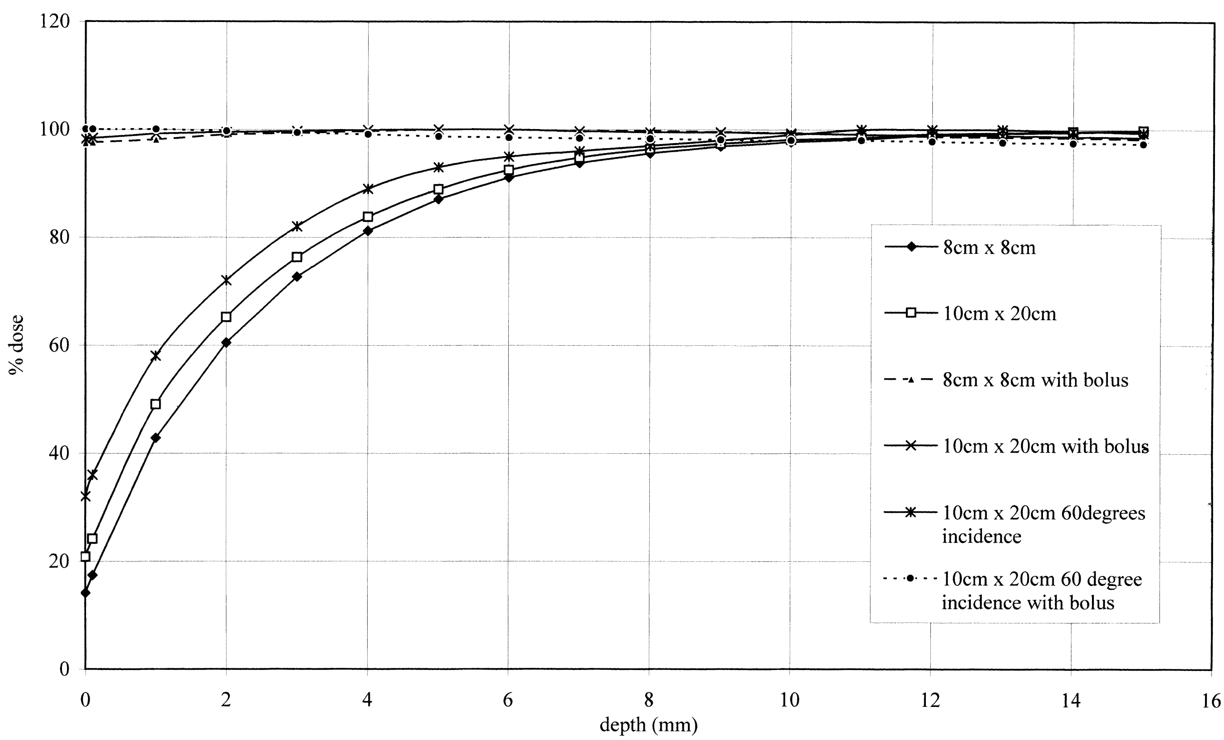


Fig. 1. Dose build up characteristics for a 6 MV x-ray beam with and without 10 mm of bolus material.

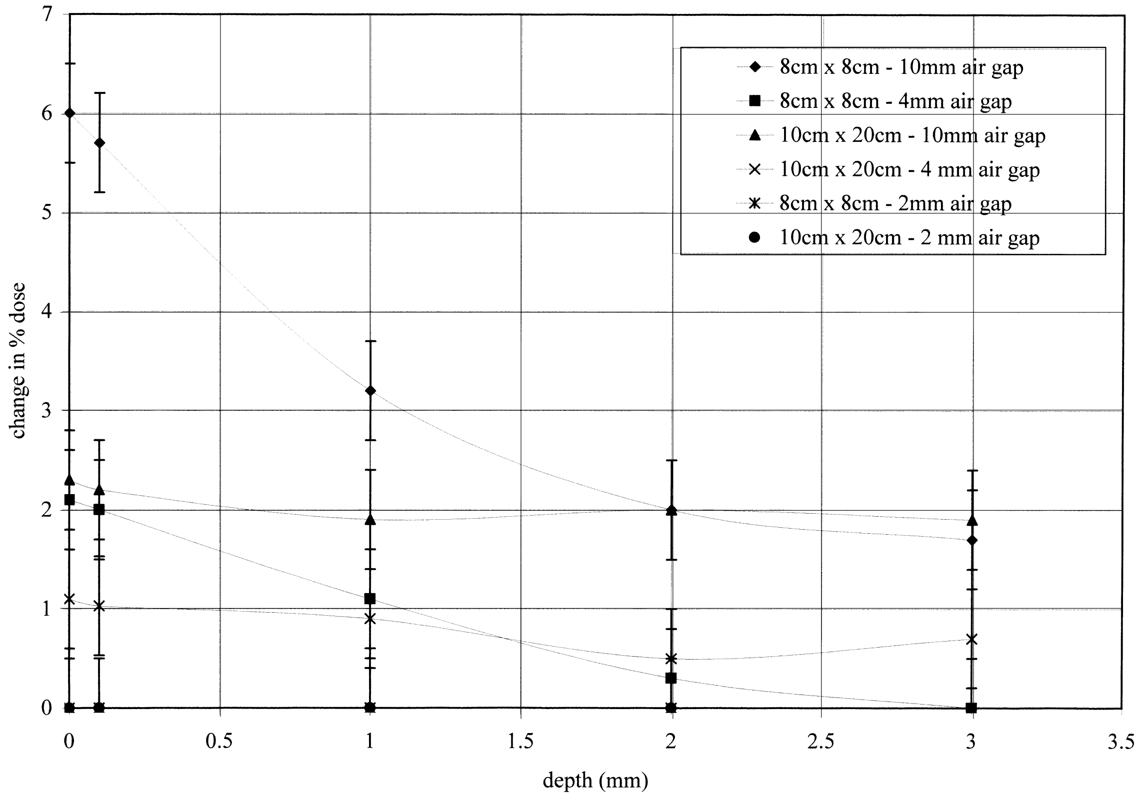


Fig. 2. Reductions in dose in the first 3 mm of phantom material caused by the varying air gaps under 10 mm of bolus.

chamber. When the angle of incidence is increased for open fields, the surface dose increases as also shown in Fig. 1 for a 10 × 20 cm field at 60 degrees incidence. Surface dose is 32% of maximum and 100% of maximum for no bolus and 10 mm bolus respectively.

Air gaps of 2, 4 and 10 mm were introduced and build up doses were measured with the Attix chamber and Gafchromic film. By subtracting the percentage dose results with the air gap from percentage dose results without an air gap, the reduction in dose delivered to the skin can be seen. Fig. 2 shows these results as measured by the Attix chamber for a 6 MV x-ray beam, 10 mm bolus at 8 × 8 cm and 10 × 20 cm field sizes with different air gaps using a smoothed line fit. A negligible result is seen for a 2 mm air gap. For a 8 × 8 cm field size a difference of 6% ± 0.5% at the surface was seen for the air gap of 10 mm. This value dropped to 2% after 2 mm depth. These values were measured as 4% ± 2% at the surface and 2% ± 2% at 2 mm depth for Gafchromic film.

Table 1 shows the reductions in surface dose associated with angle of beam incidence for an 8 × 8 cm and a 10 × 20 cm field as measured by the Attic chamber. Larger reductions are seen as angle of incidence is increased. The largest reduction in surface dose was recorded for a 8 × 8 cm field at 60 degrees angle of incidence with a 10 mm gap.

Table 1
Reductions in skin dose with oblique incident beams

| | | Gap size (% reduction) | |
|---|---|---|---|
| Field size (cm × cm) | Angle of incidence (degrees) | 4 mm | 10 mm |
| 8 × 8 | 0 | 2 | 6 |
| 8 × 8 | 15 | 2 | 6 |
| 8 × 8 | 30 | 3 | 7 |
| 8 × 8 | 45 | 4 | 8 |
| 8 × 8 | 60 | 4 | 10 |
| 10 × 20 | 0 | 1 | 2 |
| 10 × 20 | 15 | 1 | 2 |
| 10 × 20 | 30 | 1 | 3 |
| 10 × 20 | 45 | 2 | 4 |
| 10 × 20 | 45 | 2 | 4 |
| 10 × 20 | 60 | 2 | 4 |

## 4. Discussion

Bolus material is often placed on a patient's skin during radiotherapy to produce a uniform dose distribution across the treatment volume, thus effectively removing the build up effect of photon beams. Treatments for breast carcinoma, Muller-Sievers et al. (1992) or maxillary sinus carcinoma, Janjan et al. (1991) are examples of treatments where bolus material is used to increase the skin dose. Unfortunately, due to insufficient malleability of bolus material, small air gaps can be generated. The effect of these air gaps causes electronic disequilibrium to be re-established in this region and this could cause the dose directly to the patient's skin to decrease as the x-ray beam could produce secondary build up. This is also seen in the case of air cavities such as the nasophrynax or oesophagus, Wong et al. (1992). However, these cavities are larger, of the order of centimeters. Our results using small air gaps (less than 10 mm) show that minimal reduction in skin dose and, on all occasions, more than 90% of maximum dose is still applied to all skin regions. Clinically, air gaps are expected to be mostly small air pockets. Thus reductions measured in this report are the maximum likely. Electrons generated in the bolus material are mostly forward scattered exiting the bolus material and passing through the small air gap to reach the skin surface and deposit dose. A small percentage will be scattered and a small percentage will not be generated from side scattered interactions.

## 5. Conclusions

The effects of small air gaps under bolus material have been shown to produce only small decreases in surface and skin dose for radiotherapy treatment fields with at least 90% of maximum dose still delivered with a 10 mm air gap between the bolus and the skin surface. Air gaps should be avoided under bolus, however, their introduction should not produce a significant reduction in tumor control.

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