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# Evaluation of build-up dose from 6 MV X-rays under pelvic and abdominal patient immobilisation devices

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**Abstract**

The use of pelvic and abdominal immobilisation devices in radiotherapy is required for accurate positioning and repositioning of patients during their fractionated treatment delivered normally over a period of 5–6 weeks. 6 MV X-rays produced by a medical linear accelerator have a skin sparing effect whereby the skin dose delivered is considerably less than that received by the tumour. The treatment through a vacuum compressed immobilisation device (Vacbag) however increases the dose delivered to the skin by interactions of the X-rays within the Vacbag material. For example, the basal layer doses increased from 16% for an open field to 52% of maximum with a bag thickness of 2.5 cm for a 10 cm × 10 cm field at 6 MV X-ray energy. At the same field size the dermal skin layer (1 mm depth) doses increased from 44% (no bag) to 60% for a bag thickness of 2.5 cm at 6 MV X-rays. The Vacbag should be placed outside the treatment field whenever possible to keep skin dose to a minimum level. © 2002 Published by Elsevier Science Ltd.

*Keywords:* Radiotherapy; Patient immobilisation; Skin dose; Vacbag

## 1. Introduction

Often the treatment of cancer with radiotherapy requires immobilisation of the patient during irradiation. It is also required that the patient is immobilised in a reproducible way over the entire fractionated treatment period which can be as long as 6 weeks. To perform this task, various types of immobilisation devices have been created and studied (Mellenberg, 1995; Fontenla et al. 1994). For head and neck regions, head casts which mould around the patients head are used to secure the patient in the same position each time. For fixture of the abdominal region a Vacbag can be used whereby the bag becomes moulded around the patients abdominal region (Graham et al., 2000; Bentel et al., 1997; Nutting et al., 2000). Radiotherapy treatment is moving towards an increased use of multi-fractioned, multi-field and rotational treatment based on sophisticated computer technology. This demands maximum fixation accuracy. However on many occasions to provide optimal tumour dose coverage, the X-ray beam used must pass through the immobilisation device before entering the patient. Thus high skin doses can be delivered and become a limiting factor in treatment procedure (Turesson and Thames, 1989). Johnson et al. (1995) investigated the surface dose attributed to Vacbag material, however, no investigation has been performed to measure the dose at the equivalent depths of the basal and dermal layer of skin which is approximately 0.07 and 1 mm, respectively (Williams et al., 1989). This note investigates the changes in skin dose associated with treatment through Vacbag material for a 6 MV X-ray beam.

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Fig. 1. Picture of Vacbag in compressed state. The Vacbag has been moulded into an immobilisation shape for a specific patient.

## 2. Materials and methods

Measurements were performed on a Varian 2100c medical linear accelerator at 6 MV peak energy. Photon beam measurements were made using an Attix Model 449 parallel plate ionisation chamber (Rawlinson, 1992) in a solid water (Constantinou et al., 1982) stack phantom. The chamber was connected via a triaxial cable to a Keithley model 2540 electrometer at $\pm 300$ V bias voltage and an average taken between the two-recorded results. Percentage dose build-up curves were measured on the central axis for various beam configurations. No corrections for parallel plate ionisation chamber response were applied. For the Attix chamber, a $< 1\%$ correction to surface dose would be required based on the Rawlinson correction method (Rawlinson, 1992). The solid water stack phantom was constructed from many thin sheets of solid water. The solid water layers of the appropriate thickness were placed on top of the Attix chamber, which was also held in a solid water frame to minimise any perturbations caused by differences in electron density of surrounding material. The percentage dose curves were measured by comparison of measured charge at a specific depth to the maximum charge measured. The depth of maximum dose varies slightly with field size and this is taken into account for percentage normalisation. That is, the percentage dose given is the ratio of the dose recorded at the stated depth compared to the maximum dose recorded. Results are normalised to 100% at $D_{\max}$. The effective thickness of the Attix chamber front window is 0.048 mm = 0.025 mm Kapton. Errors are quoted as the mean error from the combination of negative and positive polarity measurements and the variation in five data point measurements at each experimental configuration.

The Vacbag consists of an airtight bag filled with small polystyrene spheres as shown in Fig. 1. The Vacbags are almost air equivalent when uncompressed. The outer layer of the bag is made from a tough durable plastic, which has a density of approximately 1.2 g/cm$^3$. This layer is approximately 0.2 mm thick. The Vacbag can be compressed by vacuum suction whilst the patient is in the treatment position to the required shape. Vacbags used for testing were compressed to various uniform thicknesses ranging from 0 to 10 cm. These values represent the maximum and minimum range of thicknesses, which normally occur clinically during Vacbag moulding. The Vacbags were positioned directly above the ionisation chamber with no separation between the lower edge of the bag and the top surface of the water phantom as would be the case of the patients' skin surface during radiotherapy treatment through the Vacbag.

Measurements were performed with radiotherapy field sizes ranging from 5 cm $\times$ 5 cm up to 30 cm $\times$ 30 cm which were considered most typical treatment fields. All measurements were performed at an SSD of 100 cm. This is not typical for modern isocentric set-ups which have varying SSD's for each specific patient, however, to evaluate the effects of the Vacbag with field size and thickness of material, a standard SSD was chosen.

## 3. Results and discussion

Fig. 2a shows the dose at the basal cell layer (0.1 mm effective depth) as a function of field size for four thicknesses of Vagbags. Thicknesses range from 0 to 10 cm. As can be seen the dose to the skin surface increases as field size increases but more markedly by the increase in Vacbag material. Fig. 2b shows similar results at a depth related to the dermal cell layer (1 mm). Results show for the surface dose distributions that there is a significant increase in dose for all field sizes with only 0.3 cm of Vacbag material in the beam. As a percentage of maximum dose, there is an increase of 13.5% for a 10 cm $\times$ 10 cm field and 22% for a 30 cm $\times$ 30 cm field from 0 to 0.3 cm thickness (Fig. 1a). For a further increase of bag thickness to 2.5 cm (i.e. another 2.2 cm or another 7 times the thickness), there is an increase of 23% for a 10 cm $\times$ 10 cm and a 13% increase for a 30 cm $\times$ 30 cm field. Table 1 shows the increases in skin dose at the surface (basal layer) and at 1 mm (dermal layer) depths relative to the maximum absorbed dose. There is an increase in skin dose seen with thickness of bag material. This increase seems to be relatively consistent for all field sizes for the three observed bag thicknesses.

Two different effects account for the changes in dose to the surface and skin region from Vacbag material. Firstly, the increase in dose is primarily due to photon scatter interactions produced within the bag material. The combination of the two outer bag layers produced a thickness of approximately 0.5 mm water-equivalent material. The interior is made from polystyrene balls, which have a relatively low density, compared to the outer layer. The bag material slows down existing electron contamination, which has been produced outside the patient from interactions with the linear accelerator head, block trays and the air column and creates new secondary electrons. Depending on the energy of these electrons, and the thickness of the bag material, they may be totally or partially absorbed. As larger field sizes normally

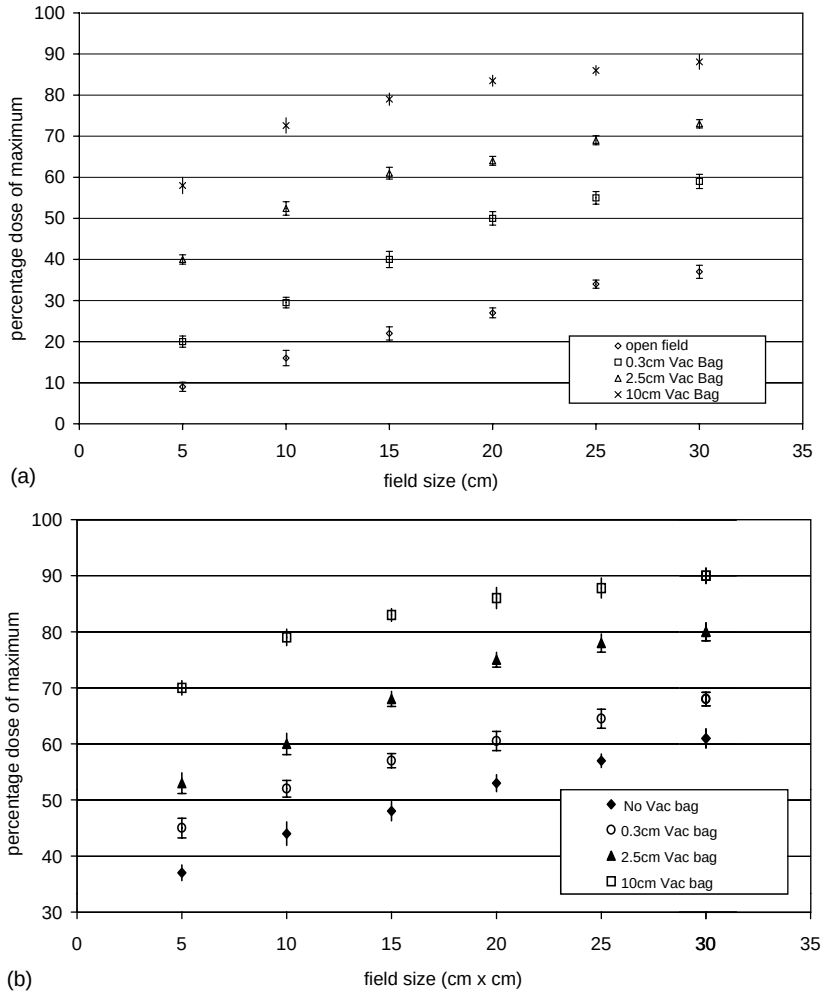


Fig. 2. Percentage doses of maximum measured at (a) the basal cell layer, and (b) with the dermal cell layer with varying thicknesses of Vacbag material in place.

have a much larger component of electron contamination in their beam, the effects within the first few mm of phantom material are expected to be larger.

Due to the nature of design of the bags, i.e. they are compressed under vacuum suction, the area through which treatment occurs cannot be cut away to reduce skin dose and often the immobilisation device is needed specifically in this region where treatment occurs. Analysis of the Vacbag positioning to provide maximum immobilisation whilst provided minimum skin dose should be investigated on a patient-by-patient basis.

## 4. Conclusion

Vacbag are one type of immobilisation devices in radiotherapy for accurate positioning of patients during their radiotherapy treatment. When treatment occurs through these devices, a significant increase in skin dose can occur which in turn could produce unwanted skin reactions. The surface dose can be almost doubled for a 10 cm × 10 cm field with only 0.3 cm of Vacbag material. Considerations for placement of immobilisation bags to be outside the treatment field whenever possible should be used to keep skin dose to a minimum level.

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Table 1
Percentage of maximum dose increases in skin dose caused by introduction of Vacbag material into 6 MV X-ray beam path

| | Field size (cm × cm) | Vacbag thickness (cm) | | |
|---|---|---|---|---|
| | | 0.3 | 2.5 | 10 |
| | | Percentage increase (of maximum dose) in dose using Vacbag compared to open field | | |
| 0.1 mm (Basal layer) | 5 | 11 | 31 | 49 |
| | 10 | 14 | 36 | 57 |
| | 15 | 18 | 39 | 57 |
| | 20 | 23 | 37 | 56 |
| | 25 | 21 | 35 | 52 |
| | 30 | 22 | 36 | 51 |
| 1 mm (Dermal layer) | 5 | 8 | 16 | 33 |
| | 10 | 8 | 16 | 35 |
| | 15 | 9 | 20 | 35 |
| | 20 | 8 | 22 | 33 |
| | 25 | 8 | 21 | 31 |
| | 30 | 7 | 19 | 29 |

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