Photon beam dose distributions for patients with implanted temporary tissue expanders

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Abstract. This study examines the effects of temporary tissue expanders (TTEs) on the dose distributions of photon beams in breast cancer radiotherapy treatments. EBT2 radiochromic film and ion chamber measurements were taken to quantify the attenuation and backscatter effects of the inhomogeneity. Results illustrate that the internal magnetic port present in a tissue expander causes a dose reduction of approximately 25% in photon tangent fields immediately downstream of the implant. It was also shown that the silicone elastomer shell of the tissue expander reduced the dose to the target volume by as much as 8%. This work demonstrates the importance for an accurately modelled high-density implant in the treatment planning system for post-mastectomy breast cancer patients.

1. Introduction

High-density implants and prostheses are known to cause local increases in dose due to lateral-scatter and backscatter of radiation, in addition to depletion of downstream dose due to attenuation [1]. The size of these dose perturbations due to the high-density media depends on the design and composition of the implant and characteristics of the incident radiation. It is currently recommended to avoid treatments where the fields pass through the high-Z media before they reach the planning target volume (PTV) to reduce uncertainty in the treatment planning stages [2] and hence the delivered dose [3]. However, this is sometimes not possible and often results in a sub-optimal treatment being delivered to the patient to avoid uncertainties in the delivered dose. This work aims to establish the dosimetric effects of a temporary tissue expander (TTE), which is a device that cannot be avoided during postmastectomy radiotherapy treatments.

It is well established that postmastectomy radiation therapy improves survival for selected breast cancer patients [4]. However, many of these patients also desire a cosmetic breast reconstruction after mastectomy, which involves the subcutaneous implantation of a TTE. The shell of the TTE is composed of a silicone elastomer membrane, which is a chemically and mechanically resistant material and is reported to be radiologically water equivalent. Additionally, a magnetic disk allows the position of the implant's valve to be determined inside the patient's body. However, this high-density disk has the potential to compromise the accuracy of radiotherapy treatment planning, and hence delivery. Here we present an investigation into the impact of the TTE on photon beam dose distributions using EBT2 film and ion chamber measurements.

2. Methodology

2.1 EBT2 film measurements
The Mentor TTE was first investigated in a radiotherapy treatment using EBT2 radiochromic film in a tissue and lung phantom. The implant was placed on 10cm planar phantom composed of an arrangement of water and lung equivalent materials with a 1cm layer of bolus positioned over the top. Then using a 6MV photon beam at an incidence perpendicular to the heterogeneity, the TTE was irradiated. The radiochromic film was placed 0cm, 2cm and 8cm downstream of the implant as well as one piece of film immediately upstream of the implant to measure any backscatter caused by the high-z material. The implant was filled with 250cc of a 0.9% saline solution before being irradiated isocentrically with 15x15cm^2 fields at a gantry angle of 0^o.

Film measurements were also taken using a CIRS IMRT thorax phantom with segmented, tangent photon fields being delivered at angles of 70^o and 250^o this time with the TTE filled with 400cc of the saline solution. This beam arrangement was adopted from a clinical plan and used a forward planned IMRT (field-in-field) technique which has been shown to provide more homogeneous dose distributions in the PTV and reduced doses in the organs at risk [5]. Each piece of film was scanned and evaluated as per the protocol outlined in Kairn [6] and Aland [7] in order to minimise the effects of film heterogeneity and scanner output variations. The dose reduction values reported throughout this study were calculated as the percentage difference between the average doses outside the shadow of the implant, relative to the doses in the region directly under the magnetic inhomogeneity. Measurement uncertainties were taken as the standard deviation of doses in each region.

2.2 Ion chamber measurements
The internal magnetic port (IMP) was removed from its silicone housing and depth dose and profile measurements were taken underneath with a Roos ionization chamber (Type 34001) and a water tank in 6 and 10 MV photon fields. These measurements were repeated in water with no IMP present for comparison. A field size of 15x15cm^2 was used. The Varian 21iX linac was continuously delivering dose at a rate of 600MU/min while the ionisation chamber recorded a series of cross-profiles and percentage depth doses. Photon profile depths were at 2, 5, 10, 20 and 30 cm for both the 6 and 10 MV beams. Percentage depth doses were taken from 2cm onwards due to a minimum scanning depth caused by the presence of the IMP.

3. Results and Discussion

3.1 EBT2 film measurements
Figure 1 (a) shows the dose profile of the implant at three different depths, downstream of the breast implant in the planar phantom for a 6MV photon beam at 0^o gantry. At 0cm, in the region directly beneath the magnetic valve, the dose is reduced by as much as 15 ± 3 %. This figure also reports a 12 ± 2 % dose reduction at 2cm and an 11 ± 2 % dose reduction as far as 8cm downstream of the magnetic disk. No backscatter dose enhancements were reported in the radiochromic film and were therefore not included.

Figure 1 (b) describes the measured attenuation effects of each component of the implant taken in the CIRS IMRT thorax phantom. It was determined that profiles downstream of the silicone elastomer/saline interface averaged doses around 8% lower when compared to profiles taken outside the implant's shadow. Differences for profiles taken under the titanium case, titanium ring and neodymium magnet were approximately 12%, 15% and 19% respectively.

Photon tangent fields were also delivered to the thorax phantom and the results in figure 1 (c) illustrate a 25% dose reduction caused by the high-density magnet in both treatment directions. Given that post-mastectomy treatments are typically delivered as per this experimental setup, the impact of the TTE on photon dose distributions would be significant if it's not accurately accounted for in planning. The insets indicate in figure 1 (b) indicate the approximate profile locations as well as

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pictographically demonstrating the perturbation caused by the TTE's internal magnet and silicone elastomer shell.

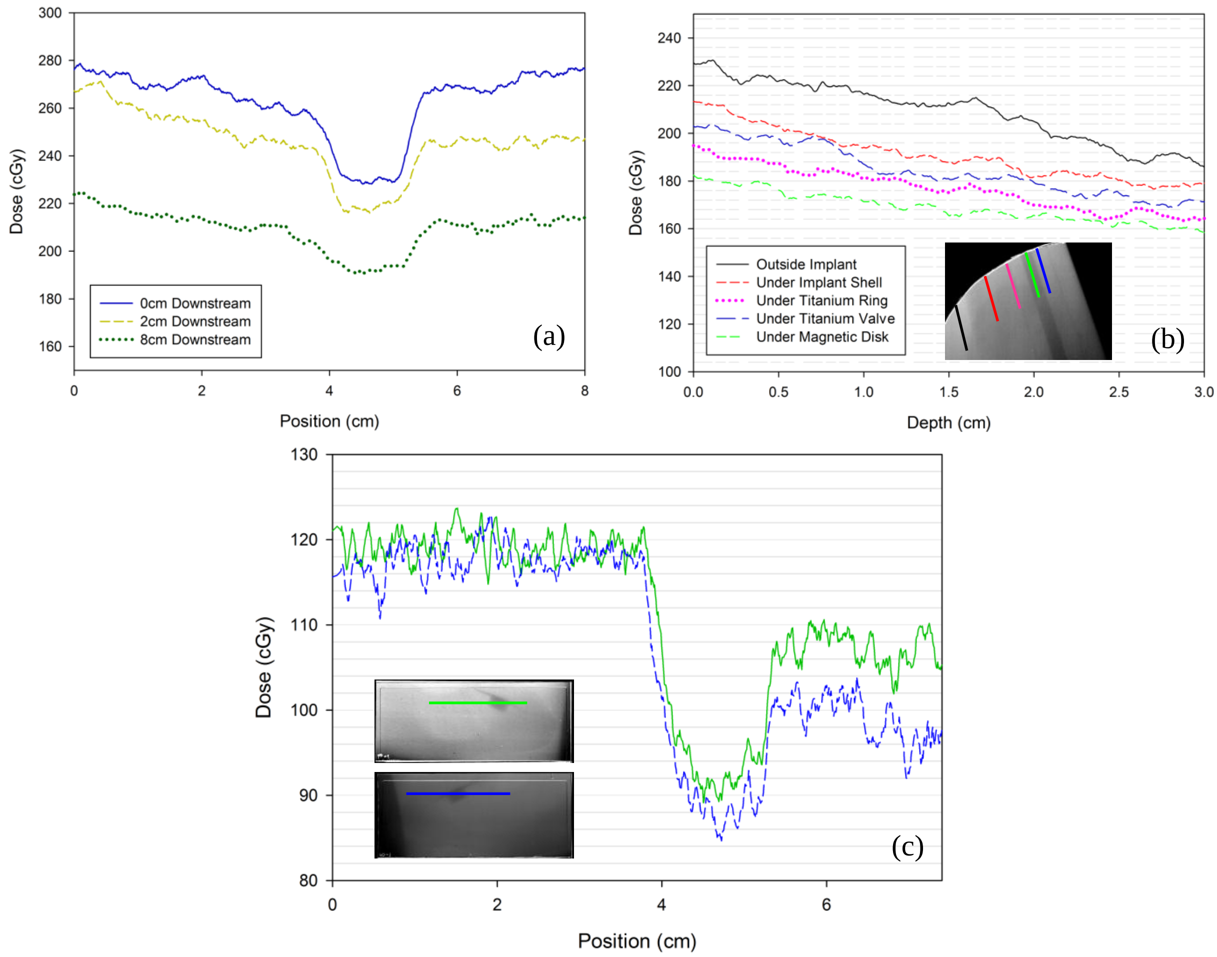

Figure 1. Film dose profiles in; (a) Planar tissue-lung phantom at 0cm, 2cm and 8cm downstream of the implant, (b) CIRS thorax phantom downstream of different components in the implant, and (c) CIRS thorax phantom for two photon beam tangents at gantry angles of 70^{o} and 250^{o}.

3.2 Ion chamber measurements

Figures 2 and 3 show dose reductions of 8% and 7% at a depth of 2cm for the 6MV and 10MV beams, respectively which are similar to our results obtained using radiochromic film. Reductions of 2% and 3% were present for both energies as far down as 30cm. While these results don't offer a direct clinical perspective on dose depletions caused by the implant, they do illustrate the effects that inhomogeneities have on photon dose distributions. In addition to the cold spots beyond the inhomogeneity caused by the greater mass scattering power in the IMP, hot spots lateral to the inhomogeneity are also produced and are most evident at 2cm in the 10MV profile in figure 2.

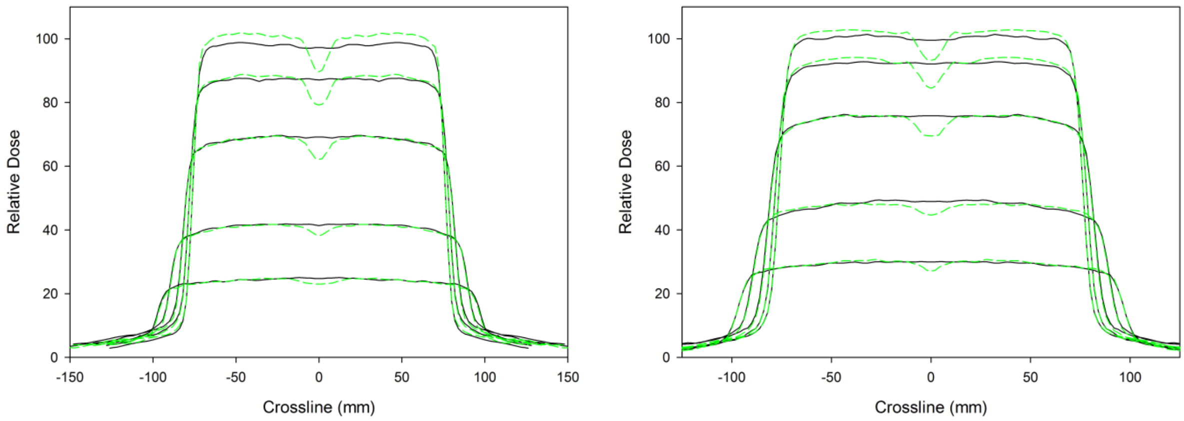

Figure 2. Cross profiles with (green) and without (black) the IMP at depths of 2, 5, 10, 20 and 30 cm for (a) 6MV and (b) 10MV photons.

4. Conclusions
This work indicates that the magnetic disk present in a tissue expander causes a dose reduction of approximately 25% in photon tangent fields immediately downstream of the implant. The silicone elastomer shell of the Mentor implant has also been shown to reduce the dose to the target volume by as much as 8%, which in turn reduces the probability of tumour control. Each component of the TTE attenuates the radiation beam to different degrees. This highlights the importance for an accurately modelled high-density implant in the treatment planning system for post-mastectomy patients.

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