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Technical note

Dosimetric effects of brass mesh bolus on skin dose and dose at depth for postmastectomy chest wall irradiation

Zakiya S. Al-Rahbi[a,b], Dean L. Cutajar[a,c], Peter Metcalfe[a,d], Anatoly B. Rosenfeld[a,d,*]

[a] Centre for Medical Radiation Physics (CMRP), University of Wollongong, Australia
[b] Radiotherapy Department, National Oncology Center, The Royal Hospital, Muscat, Oman
[c] St George Cancer Care Centre, St George Hospital, Kogarah, Australia
[d] Illawarra Health Medical Research Institute, University of Wollongong, Australia

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ABSTRACT

Purpose: To investigate the feasibility of using the brass mesh bolus as an alternative to tissue- equivalent bolus for post mastectomy chest wall cancer by characterizing the dosimetric effects of the 2-mm fine brass bolus on both the skin dose, the dose at depth and spatial distribution.

Materials and methods: Surface dose and percent depth dose data were acquired for a 6 MV photon beam in a solid water phantom using MO*Skin*™, Gafchromic EBT3 film and an Advanced Markus ionization chamber. Data were acquired for the case of: no bolus, Face-up bass bolus, Face-down brass bolus, double brass bolus, 0.5 cm and 1.0 cm of Superflab TE bolus. The exit doses were also measured via MO*Skin*™ dosimeter and Markus ionization chamber. Gafchromic EBT3 film strips were used to plot dose profile at surface and 10 cm depth for Face-up brass, Face-down brass, double brass, 0.5 cm and 1.0 cm of Superflab TE bolus.

Results: The surface dose measured via MO*Skin*™ dosimeter increased from 19.2 ± 1.0% to 63.1 ± 2.1% under Face-up brass discs, 51.2 ± 1.2% under Face-up brass spaces, 61.5 ± 0.5% under Face-down brass discs, and 41.3 ± 2.1% under Face-down brass spaces. The percentage difference in the dose measured under brass discs between Face-up versus Face-down was less than 2% for entrance dose and 10% for exit dose, whereas the percentage difference under brass spaces was approximately 3% for entrance dose and about 5% for the exit dose. Gafchromic EBT3 film strip measurements show that the mesh bolus produced ripple beam profiles due to the mesh brass construction.

Conclusions: Brass bolus does not significantly change dose at depth (less than 0.5%), and the surface dose is increased similar to TE bolus. Considering this, brass mesh may be used as a substitute for TE bolus to increase superficial dose for chest wall tangent plans.

1. Introduction

Post-mastectomy radiotherapy (PMRT) has been proven to increase the locoregional and the overall survival of patients with high-risk breast cancer [1–3]. The chest wall is the most frequent site of recurrence and delivering adequate radiation doses to the chest wall is crucial to reducing the risk of treatment failure [4]. The chest wall is a challenge to treat with radiation therapy due to its irregular surface contours, large curvature and near-surface target volume [5].

The most widely used treatment modality for patients with chest wall breast cancer is megavoltage photon external-beam radiotherapy, particularly utilizing the tangential beam arrangement. Megavoltage photons are usually used for their depth penetration properties whilst providing for skin sparing effects. For 6-MV photons, the depth of maximum dose (d_{max}) is 1.5 cm, with the surface dose substantially lower. For opposed tangential fields, the skin receives approximately 80% of dose prescription due to this sparing effect [6]. Thus, the skin sparing effect of the MV beam is not desired in the case of the chest wall, where the target extends to the skin, based on the definition of the Radiation Therapy Oncology Group (RTOG) for the chest-wall target volume [7].

Tissue-equivalent material bolus is commonly used during post-mastectomy radiotherapy to provide an adequate dose build-up in the skin and superficial chest wall [5,8]. Commercially available tissue-substitute materials are Superflab and Vaseline based boluses. Previous studies have shown a few limitations of using these types of boluses.

* Corresponding author at: University of Wollongong, Northfields Ave, Wollongong, NSW 2522, Australia.
E-mail addresses: zsar264@uowmail.edu.au (Z.S. Al-Rahbi), deanc@uow.edu.au (D.L. Cutajar), metcalfe@uow.edu.au (P. Metcalfe), anatoly@uow.edu.au (A.B. Rosenfeld).

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One of these is the lack of conformity to the chest wall due to its thickness, rigidly and inflexibility, which will reduce the efficiency of the build-up material, as it has been shown that the surface dose may decrease by as much as 10% for air gaps up to 10 mm [9]. Anderson et al. (2004) reported that the effect of the air gap between the skin of the patient and the bolus may lead to harmful hot spot doses or underdosage [10].

A second issue with tissue-equivalent bolus has been identified by Ordonez-Sanz et al. [11]. They demonstrated is the difficulty in maintaining a uniform thickness across the bolus surface when Vaseline boluses are used. The bolus was shown to be very thin at the most anterior part of the breast, providing less build-up material, leading to less dose at the skin.

Another drawback of tissue-equivalent bolus is the requirement of two treatment plans (one for the bolus and the other plan for no bolus) due to the attenuation differences in the absence and presence of the bolus. The need for two treatment plans increases the workload for centers, which use the TE bolus.

An alternative to tissue-equivalent bolus that has been adopted by some institutions is brass mesh bolus. In 2008, the Radiation Oncology Department at the University of California, Davis (UCD) started using a fine brass mesh bolus (Whiting & Davis, Attleboro Falls, MA) when delivering post mastectomy radiotherapy (PMRT) as an alternative to tissue equivalent (TE) bolus [6].

The brass mesh bolus is constructed using a regular mesh of interlinked brass discs, where brass discs are interlocked together to form a mesh, as shown in Fig. 1. It has thickness of 1.5 mm, a density of 8.73 g/cm^3 and a cross section of 45 × 45 cm^2 [12,13].

Like a traditional TE-bolus, the brass bolus decreases the radiation buildup depth and thereby increases the radiation dose delivered to the skin. The strongest advantage of the brass bolus over tissue equivalent bolus, as previously reported [6,11,14], is the ability to conform to the irregular contours of the chest wall with fewer gaps, which is better than TE- bolus material. Furthermore, the local control for the surface skin reaction has been shown to improve to moderate erythema, when brass bolus used [15]. Healy et al. [6] investigated the clinical use of brass mesh as an alternative to TE- bolus for patients treated with postmastectomy chest wall radiation therapy. They concluded that when brass mesh is used in the chest wall PMRT, the majority of patients (88%) at the end of treatment achieved moderate erythema at cumulative radiation doses of approximately 5 Gy for the skin and the surface doses ranged from 81% to 122% of the prescribed dose.

Another benefit of using brass mesh bolus is the reduced impact on the dose at depth compared to tissue-equivalent bolus [11,16]. The results from the study performed by UCD, during the commission of the clinical use of brass mesh, demonstrated that the brass mesh bolus did not influence the dose below d_{max} and that monitor unit (MUs) did not change significantly with its use. Consequently, the use of a brass mesh reduces the complexity of accounting for a bolus in simulation and treatment planning and as such only one treatment plan is required [6].

Fig. 1. Brass mesh bolus.

The goal of this research is to investigate the feasibility of using the brass mesh bolus as an alternative to tissue- equivalent (TE) bolus for post mastectomy chest wall cancer by preforming dosimetric characterizations of the 2-mm fine brass mesh bolus in particular, the effect of brass bolus on dose build-up at the surface (beam entry and exit), as well as beam profiles and percentage depth doses. What is unique in this study is that the measurements were performed with MO*Skin*™ dosimeter. MO*Skin*™ dosimeter has compact size and extra resolution, thus achieving more accurate skin measurements under the fine structure of the brass spaces and discs. The different configurations compared in this work are: Face-up brass bolus, Face-down brass bolus, double brass bolusand TE-Superflab bolus, as shown in Fig. 2. The construction of the mesh brass bolus is different from both side, as shown in Fig. 2 a-b.

2. Materials and methods

2.1. MoSkin dosimeter calibration

The MO*Skin* is a particular type of MOSFET dosimeter, which has been designed and developed by the Centre for Medical Radiation Physics (CMRP), University of Wollongong (UoW), Australia. It is composed of a p- MOSFET die of approximately 350 μm thick and size 0.6 × 0.8 mm^2 and it has an active radiation sensitive volume (SV) of 4.8×10^{-6} mm^3 , which is a gate silicon oxide with thickness of 0.55 μm , embedded into a Kapton strip with a thickness of 0.50 mm, width 3 mm and strip length of 30 cm [17] . A special packaging technology, which is known as 'drop in sensor packaging' was developed at CMRP and providing a highly reproducible WED of approximately 0.07 mm that make the MO*Skin* suitable for the skin dosimetry.

Clinical use of the MO*Skin* system have been reported [18–21]. These studies showed the feasibility and reliability of using the MO*Skin* as an *in vivo* skin dosimeter in megavoltage external photon beam radiotherapy. That is due to its considerable advantages, such as good spatial resolution, high sensitivity, real time read-out without deterioration of information, negligible radiation field perturbation owing to their small size and ease of use. Particularly, MO*Skin* can provide water equivalent depth (WED) measurements at a depth of 0.07 mm as recommended by the ICRP for skin dosimetry [22], making it a suitable dosimeter for measuring skin dose in real time during treatment.

The utilised MO*Skin* probes in this study were connected by a 5-meter cable to the MO*Skin* conventional wired data acquisition system that connected to the laptop, and all measurements were carried out under a Varian Clinac 21EX Linear accelerator (Varian Medical Systems, Palo Alto, CA). They were calibrated at the reference condition using a 30 × 30 × 5 cm^3 slab water phantom. A calibration factor, CF (mV/cGy) was acquired by dividing the average threshold voltage shift ΔV (mV) by the delivered dose (cGy), in this work the delivered dose was 40 cGy, as shown in the following equation.

$$CF = \frac{\Delta V(mV)}{Dose(cGy)}$$

2.2. Attenuation effect of brass mesh bolus

The effect of the attenuation of the brass mesh bolus on the dose deposition was evaluated using an advanced Markus parallel-plate ionization chamber 0.02 cm^3, Model 34,045 (PTW Freiburg, Germany). The physical effective point of measurement for the Markus chamber is defined as 0.03 mm, at the inner surface of the proximal collecting plate. The plate separation is fixed at 1 mm; the guard ring is 2 mm and the external dimensions are 30 mm diameter × 14 mm. The Markus