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Comparison of Dose Distribution Effects for Various Bolus Materials in Electron Conformal Radiotherapy

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Abstract

In this study, the effects of various bolus materials on dose distributions were compared in electron conformal radiotherapy (ECRT). Superflab, Super Stuff pink wax and Paraffin wax bolus materials are used with 15 MeV electron energy for dosimetric comparison. Additionally, 10 mm thick Super Stuff pink wax bolus and paraffin wax bolus materials were placed on the right eyelid of a patient. Using electron dose calculation algorithm and ion chamber measurements, dosimetric comparisons were made in the Eclipse treatment planning system (TPS). Both for measured and calculated dose, values were acquired 3 times and averaged for each case. Resulting differences are expressed as percentage differences. Dose differences were obtained in measurements with and without using bolus at several locations of the solid phantom, performed by the Roos Ion chamber. Dosimetric differences of 7-7.5% for Superflab, 10-10.5% for paraffin bolus and 13-14% for Super Stuff pink wax bolus are obtained. Besides, when dosimetric comparisons are made in the treatment planning system for cases with and without bolus; Dose differences were calculated to be 2-2.5% for superflab silicon bolus, 3-3.5% for paraffin wax bolus and 5-6% for Super Stuff pink wax bolus. To increase skin dose in curved anatomical structures in radiotherapy, it is safe to use the paraffin wax bolus material in radiotherapy clinic, as an alternative to Superflab silicon bolus and Super Stuff pink wax bolus materials, due to its low cost and ease of conforming to body surface contours.

Keywords: Radiotherapy, superflab, paraffin, super stuff, bolus

1. Introduction

Due to the high penetration property of X-rays, Electron conformal radiotherapy (ECRT) technique is preferred in radiotherapy (RT) practice to achieve more effective skin dose for superficial tumor [1]. When using electron beams, bolus materials are applied to the skin achieving an increase in skin dose and avoiding unwanted exposure for surrounding healthy tissues [2]. Various bolus materials are produced and commercially available for his purpose [3-4]. In addition to having specific electron and material density and being tissue or water equivalent, the bolus material should be flexible enough to obtain the shape skin contour [5-6]. It is relatively easy to calculate the dose distribution of photon, electron or combined radiation beams interacting with smooth surfaces with a uniform geometry, however, calculating the dose profile gets more complex when irregular anatomical structures and tissue heterogeneity is present. [7-8].

To alleviate this difficulty and improve treatment outcome, Bolus materials are used to enhance isodose curve conformity to tumor tissue geometry. When placed on the patient's skin, bolus material creates an appropriate surface of physical interaction for incoming radiation by compensating for missing tissue and flattening inclined surfaces. [9-10].

Presence of an air gap between the bolus and the patient's skin may cause unwanted dose distribution profiles, especially in the skin and near the skin due to density difference between tissue and air [11-12]. Therefore, it is of great importance that the bolus material has fully adhered to the anatomical region where it is applied. In some cases, air pockets of few millimeters (mm) may occur in the treatment area due to insufficient flexibility of the bolus material. During the irradiation, these air pockets cause a drop-in dose value regionally due to loss of electronic balance in the air-tumor interface [13]. Therefore, to precisely determine the absorbed and measured doses, assays for quality assurance should be performed to determine changes in dose levels. Different types of ion chambers, film and TLD (Thermoluminescence Dosimeter), etc. different dosimeters are used for quality assurance purposes.[14]. Studies comparing various bolus materials such as; thermoplastic sheets, blue water phantoms, 3D customized bolus, wet gauze, standard commercial bolus material (Superflab), custom prepared silicone dental impression material and play dough material are found in literature [15-16]. Data obtained in these studies almost always stress the fact that air gaps between the bolus and the patient causes unwanted artifacts and should be minimized. In addition, bolus materials should be flexible enough to be easily given shape in order to conform to the application surface on the body.

In this study, the effects of ECRT, Superflab, Super Stuff Pink Wax and Paraffin wax bolus materials on dose distribution are comparatively evaluated using ion chamber measurements and dosimetric calculations obtained with treatment planning system (TPS). Radiotherapy TPS calculations were performed on computed tomography section of a patient with right eyelid tumor lesion to compare dosimetric differences in skin dose when Superflab, Super Stuff Pink Wax and Paraffin wax bolus materials are applied.

2. Materials and Methods

2.1. Bolus Materials

In our study, we used three different bolus materials, Superflab, Super Stuff Pink wax and Paraffin wax. Superflab silicon bolus (Eckert & Ziegler BEBIG), is a tissue equivalent material with density 1.02 g/cm^3, Hounsfield Unit (HU) = 0 equivalent material. Superflab is exceptionally elastic, conforming to patient contours, while maintaining uniform thickness.

Super Stuff Pink Wax bolus (by CMS Alphatech) has a density of 1.03 g/cm^3. It is packaged in a plastic bag with a black water fill line indicated on the bag. When mixed with cold water it forms a jelly-like consistency. It is wrapped with plastic and shaped to fit the patient.
Paraffin wax bolus (Chemact (Liaoning) Petrochemicals Ltd.) is a complex mixture of hydrocarbons, composed of predominantly carbons atoms with a density of 0.95 g/cm^3. It is white color, odorless and mechanically stable. It is widely used in high-quality candle making, packaging and cosmetics.

2.2. Measurement setup preparation on RW3 Solid Phantom

To achieve a back-scatter balance, Roos Chamber (PTW-Freiburg type 34001, Germany) was placed between two RW3 solid slab phantoms. The below phantom being 10 cm (dmax) and upper phantom being 3 cm (dmax) in depth. Spot dose measurements were taken respectively, with Superflab silicone gel layer type bolus, Super Stuff pink wax bolus and paraffin wax bolus materials, placed on the RW3 solid phantom (Figure 1). In each case, a bolus material of 10 cm x 10 cm x 1 cm is used.

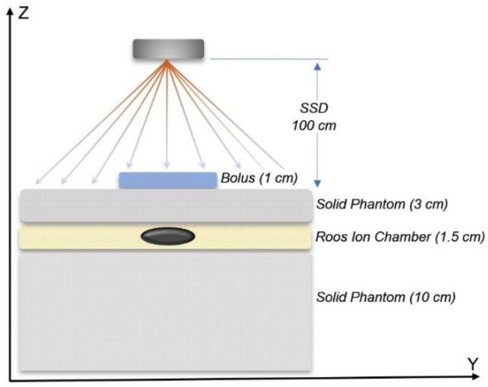

Figure 1. Dose measurement setup with Roos type ion chamber, solid phantom and bolus material.

2.3. Data Acquisition and TPS Calculations

The spot dose values at the center (x, y, z = 0) point, x = ± 2 cm and y = ± 2 cm at 3 cm depth are measured with and without bolus on the solid phantom using 15 MeV electron energy and 100 monitor unit (MU) produced with the Primus linear accelerator (Siemens, Germany) present in our clinic. In the TPS calculation, CT images of 3 mm slice thickness are acquired (Somatom Definition, Siemens, Germany) are acquired and fed into the Eclipse Treatment Planning System $V_{8.9.08}$ (Varian Medical Systems, USA), dose calculations are performed using the electron dose algorithm. Absorbed dose values are calculated at center (x, y, z = 0) point, x = ± 2 cm and y = ± 2 cm at 3 cm depth (maximum dose depth) of solid phantom using electron energy of 15 MeV and 100 cGy/fr dose. Both in Roos Chamber measurements and TPS dose calculations, a Skin Source Distance (SSD) of 100 cm, 100 MU, Gantry and Collimator angle of 0° were selected.

2.4. Radiotherapy of skin lesion using Bolus Materials

For a patient with lesion on right eyelid, both RT and TPS calculation is performed with and without bolus

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material. Patient consent was obtained before the procedure. RT was performed without bolus and respectively with 10 mm thick Super Stuff pink wax bolus and paraffin wax bolus placed on patient's right eyelid. Using the same setup, treatment planning is performed with Eclipse TPS for the bolus-free, Super Stuff pink wax bolus and paraffin wax bolus cases. In all treatment plans 15 MeV electron energy, 60 Gy/30 fr dose and gantry angle of 340° is used which best suited to the patient's anatomic structure. Skin doses were compared for all cases with and without bolus materials.

2.5. Statistical Analysis

Both for measured and calculated dose, values were acquired 3 times and averaged for each case. Resulting differences are expressed as percentage differences.

3. Results

Measurements are obtained with Roos Chamber instrumentation at a depth of 3 cm in solid phantom, while the location of the ion chamber varied, respectively at the center (x, y, z = 0) point, x = ±2 cm and y = ±2 cm. Dose differences in percent are compared to the no bolus case. For Superflab silicone gel layer type bolus a difference of 7-7.5%, for paraffin wax bolus, 10-10.5% and for Super Stuff pink wax bolus a difference of 13-14% were calculated (Table 1).

RW3 solid phantom and ion chamber measurement setup with 3 mm cross-sectional CT images used in treatment planning with and without bolus; Dose differences of 2-2.5 % for superflab silicon bolus, 3-3.5 % for paraffin wax bolus and 5-6 % for Super Stuff pink wax bolus were calculated (Table 2).

Table 1: Roos Chamber and solid phantom spot dose measurement differences for Superflab silicone bolus, paraffin wax bolus and Super Stuff pink wax bolus.

Bolus Material	Dose Difference between Bolus and No Bolus Cases				
Point Dose Locations	**x = 2 cm**	**x = -2 cm**	**Central Dose**	**y = 2 cm**	**y = -2 cm**
Superflab Silicone Bolus	4.7 %	7.8 %	7 %	7.4 %	7.4 %
Paraffin wax Bolus	10 %	10.5 %	9.7 %	9.7 %	10.7 %
Super Stuff pink wax Bolus	13.9 %	14.4 %	13.4 %	13.9 %	13.4 %

Table 2: TPS dose calculations for Superflab silicone bolus, paraffin wax bolus and Super Stuff pink wax bolus.

Bolus Material	Dose Difference between Bolus and No Bolus Cases				
Point Dose Locations	**x = 2 cm**	**x = -2 cm**	**Central Dose**	**y = 2 cm**	**y = -2 cm**
Superflab Silicone Bolus	2 %	2.3 %	2.5 %	1.8 %	2.1 %
Paraffin wax Bolus	3.3 %	3.1 %	3.2 %	2.8 %	3.8 %
Super Stuff pink wax Bolus	5.2 %	2.5 %	5.9 %	4.9 %	4.8 %

In the TPS, the target volume is contoured approximately 3 mm below the body line (skin surface) to avoid low doses in dose volume graphs (DVH) due to the build-up effects. For the patient with a lesion on the right eyelid, a separate skin tissue was contoured in the TPS with a thickness of 2 mm and a volume 4.7 cm^3 underneath the body line (Figure 2). Using the Super Stuff pink wax bolus and paraffin wax bolus materials, the difference between the skin doses obtained in DVH was calculated as 3.5 % on average and the difference between the minimum doses was calculated as 10.8 % (Table 3).

Table 3. Differences in skin dose using Superflab, Super Stuff pink wax bolus and paraffin wax bolus.

Minimum Dose	Superflab Silicone Bolus	Super Stuff pink wax	Paraffin wax Bolus
Maximum Dose	2 %	2.5 %	2.1 %
Mean Dose	3.3 %	3.2 %	3.8 %
Median Dose	5.2 %	5.9 %	2.8 %

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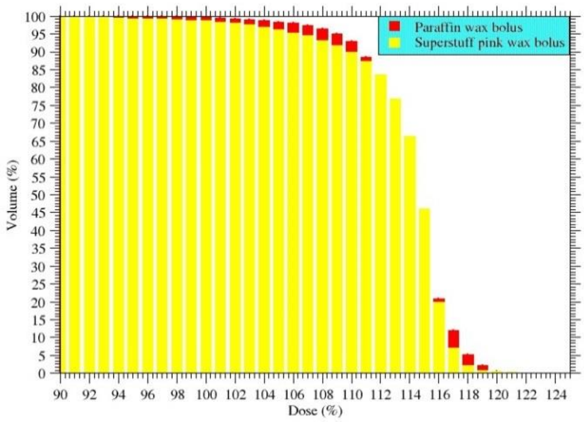

Figure 2. Skin dose volume graph obtained with Super Stuff pink wax bolus and paraffin wax bolus material.

4. Discussion

Materials used in the clinical practice as a bolus must be non-toxic, easy to produce, durable, inexpensive and flexible. Besides, the bolus must provide a homogenous dose distribution in the target volume.

The effect of bolus material on dose distributions when Megavolt (MV) level photon or electron energy applied is reported in the literature. According to a study done by Kong et al. using three different energies; it has been reported that the effect of an air gap between skin and bolus material causing dosimetric differences are linked to the energy of the incoming electron beam, the size of the air gap and the bolus thickness [17].

Kim et al. demonstrated that, in electron conformal RT, bolus use is an effective and feasible treatment in patients with irregular anatomic structures. They also emphasized that this approach could be a supplementary standard treatment to reduce local recurrence [18]. Hsu et al. compared dosimetric changes in surface dose with Superflab bolus material and using different bolus materials for conventional and intensity modulated radiotherapy (IMRT) treatment techniques. The dose difference between Superflab and Aquaplast was close and no significant difference was calculated in surface doses for conventional and IMRT techniques [19].

Al-Rahbi et. al calculated the absorbed and skin dose when using Brass mesh and Superflab bolus materials. The Brass mesh bolus did not show significant dosimetric differences (<0.5 %) at various depths and the skin dose increase was similar to using Superflab bolus. According to their findings, it was reported that Brass mesh bolus could be used in addition to Superflab bolus [20].

In this study, point dose values in solid water equivalent phantom calculated with TPS are compared with Roos ion chamber dose measurements for ECRT. We observed percent differences between point dose values obtained in TPS for Superflab bolus, paraffin wax bolus and Super Stuff pink wax bolus materials. Also, we note that dosimetric differences were higher in ion chamber measurements. We have shown dosimetric differences and these are thought to occur due to the dose variability in the build-up region and the incompatibility of actual measured dose profiles transferred to TPS and the dose profiles obtained when using various dose calculation algorithms in TPS (Table 1 and Table 2).

Considering the physical properties of the paraffin bolus material such as its density, flexibility of application to irregular anatomy, we obtained comparatively similar results as reported in the literature, with respect to measured and calculated doses for Superflab and Super Stuff pink wax. We first used the ECRT technique with the paraffin bolus material to calculate the dose measured in the ion chamber as well as the dose calculated in TPS, Superflab and Super Stuff pink wax bolus materials. We have not come across a similar study reported in the literature and we believe that our dosimetric findings would be a basis for future studies.
The bolus material must be in full contact with the anatomical region, however, in RT treatment of head and neck tumors, due to the inflexibility of the applied bolus material, air gaps of few mm may occur in certain parts of the treatment region. In our study, 15 MeV electron energy is preferred considering the patient's skin lesion and its depth. Dosimetric differences were obtained between the measured and calculated doses for different bolus materials, with respect to their physical properties, water-tissue equivalency and application efficiency.

Super Stuff pink wax bolus and paraffin wax bolus materials were separately applied to the lesion on the right eyelid. TPS calculation showed significant dosimetric differences in skin dose under the body line with 2 different bolus and without bolus material (Figure 2). Considering the dosimetric differences obtained due to different bolus materials, we recommend clinical application of the bolus material only after comparison ion chamber should be applied in the clinic after comparison.

When Superflab silicone bolus material was used on the patient's eyelid, we observed in skin dose calculations that it was not effective in RT application due to the formation of ~5 mm air pocket. Due to this, Superflab bolus material was not used for skin dose calculations. In our study, we conclude that paraffin wax bolus material is superior in RT application compared to Super Stuff pink wax bolus material in terms of skin dose for lesion treatment in eyelid region with the curved anatomical structure.

5. Conclusion

In this study, ion chamber dose measurements and TPS dose calculations are compared when Paraffin bolus, Superflab silicon bolus and Super Stuff pink wax bolus materials are used to increase the skin dose for curved regions in RT. The use of Paraffin bolus yielded superior results compared to other bolus materials in terms of cost, measured dose, flexibility to conform to the anatomic region.

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Author's Contributions

Serhat Aras: Wrote the initial manuscript, performed the experiments and analytical analysis.

İhsan Oğuz Tanzer: Wrote the final manuscript and revised the analytical analysis, result interpretation and manuscript revision.

Türkan İkizceli: Assisted in the revisions and final manuscript.

Ethics

There are no ethical issues after the publication of this manuscript.

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