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Investigation of Effect of Air Gap between Surface and Bolus on Dose Distribution for 6 MV Photon Beam

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Abstract

In radiotherapy, tissue equivalent boluses are frequently used in the treatment of superficially located tumors. The air gap between the patient's skin and the bolus may cause dosimetric uncertainties. This study aims to dosimetrically investigate the effect of the air gap between the surface and the bolus on dose distribution. Computed tomography (CT) images of the phantom were obtained and transferred to the treatment planning system (TPS). In the TPS, a bolus was placed on the phantom surface and then air gaps were created between the bolus and the surface. The effect of the air gaps between the surface and the 5 mm thick bolus on the dose distribution was analyzed with the point doses obtained from the TPS. For the 6 MV X-ray, it was observed that the air gap negatively affected the surface doses calculated by TPS. Accordingly, an inverse correlation was found between air gap and surface dose. It is recommended that bolus use, especially in curved anatomical regions, should be applied before CT scanning as much as possible. When using bolus material in radiotherapy, it is recommended to be careful not to leave an air gap between the surface and the bolus.

Keywords: Air-gap effect, Bolus, Radiotherapy, Skin dose

1. Introduction

The main goal of radiotherapy is to deliver the necessary dose to the target volume while ensuring that the surrounding critical organs are protected in the best possible way [1, 2]. In this way, the tumor is destroyed and the patient's quality of life is improved. Treatment planning systems (TPS) are used for dose calculation in radiotherapy. Dosimetric measurement data obtained for each treatment device are uploaded to the TPS. Using this data, TPSs provide dose calculation to the user through different algorithms. High-energy photon energy is used in radiotherapy and the lowest X-ray energy used is usually 6 MV [3, 4]. The maximum dose values of these rays occur at different depths depending on the energy. For 6 MV X-rays, the maximum dose depth is approximately 1.5 cm [5]. As the size of the energy used increases, the depth of the maximum point also increases.

The dose accumulated at the point where the beam of radiation comes into contact with the patient's surface is not the maximum dose and this is called the skin-sparing effect in radiotherapy. Therefore, the skin is protected by the nature of high-energy photon beams [6]. While this is an advantage in radiotherapy of deep-seated tumors, it can be a disadvantage in superficial tumors. In the radiotherapy of superficially located tumors, a tissue-equivalent material called bolus is used to overcome the skin-protective properties of high-energy photon beams [7, 8].

Bolus is a tissue-equivalent material in contact with the skin in the area to be irradiated and is used to increase the surface dose in photon and electron treatments [9]. The bolus must have an electron density, physical density and atomic number equivalent to that of tissue or water, as well as being flexible and malleable to easily take the shape of the skin contour. It is also important for clinical use that it is transparent to facilitate the adjustment of the irradiated area, is not affected by high dose levels, is durable, non-toxic, non-flammable, does not allow the growth of bacteria and fungi and has an acceptable cost [10]. Boluses made from tissue equivalent materials are divided into two groups, Super-Flab or Super Stuff. Super-Flab boluses are specific thicknesses and are prepared in advance and irradiated in gel layers in the irradiation area. they can land on it. Super-stuff boluses form in the transporter field are boluses that can solidify.

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Usually, the most commonly used bolus type is Super-flab are boluses. Super-flab boluses have a mass of 1.02g/cm^3 and the raw material is vinyl. The thickness of the bolus material to be used varies depending on the distance, thickness and location of the tumor to the skin. Contact of the bolus material with the skin surface is extremely important. There is usually no problem with bolus use in anatomically flat areas. However, in anatomically irregular areas, the air gap between the patient's skin and the bolus may cause dosimetric uncertainties [11, 12].

This study aims to dosimetrically investigate the effect of the air gap between the surface and the bolus on dose distribution.

2. Materials and Methods

2.1. Phantom design

Since the current study was not performed on patients, solid water phantoms consisting of water-equivalent plates were used to provide the required depth. Solid phantoms are a water-equivalent material used for dosimetry procedures in calibration and quality control protocols of high-energy X-ray and electron beams in radiotherapy. In this study, PTW FREIBURG brand RW3 model 30x30x1 cm solid water phantoms (PTW, Freiburg, Germany) were used. For irradiation of RW3 solid phantoms in treatment planning system (TPS), images of the phantom were obtained on a Toshiba Aquilion S4 Computed tomography (CT) device (Toshiba Medical Systems, Japan). The obtained CT images were TPS.

2.2. Bolus material

The high-energy photons used in radiotherapy have skin protective properties. In this study, a tissue equivalent bolus material was used to ensure that the phantom surface received enough dose. The bolus was created virtually in TPS. The phantom created in the TPS was tissue equivalent and had a density of 1 g/cm^3. Air gaps were created to examine the effect of the air gap between the bolus and the surface on dose distribution. The air gaps between the bolus and phantom surface were 0, 1, 3, 5 and 10 mm, respectively. The bolus thickness created via TPS was 5 mm.

2.3. Dose calculation

In Eclipse TPS, dose calculations were performed using the AAA algorithm. An area of 10x10 cm^2 was determined for the beam area. To evaluate the effect of source surface distance (SSD) on dose distribution, plans were created at 3 different SSDs. These SSDs were 95, 97.5 and 100 cm, respectively. For all plans, the gantry angle was 0 degrees and the prescription dose was 200 cGy. X-ray energy for all plans was 6 MV. For each SSD, beam plans were created for 0, 1, 3, 5 and 10 mm air gaps between the bolus and phantom surface. The plan created for a 5 mm air gap and SSD= 97.5 cm is shown in Fig 1. Surface doses for each plan were obtained by point dose reading with the same standards.

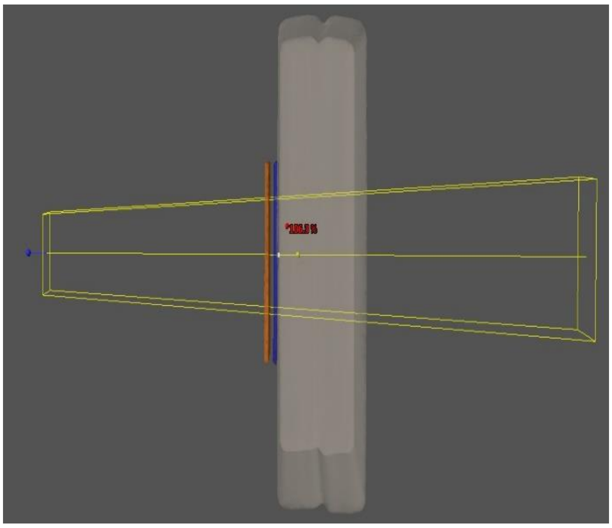

Figure 1. Beam field without air gap (blue) and with 5 mm air gap (orange) for SSD=97.5

3. Results and Discussion

A change in surface doses was expected according to the change in SSD'. As a result of the calculations made in TPS, the surface doses were 199.6, 175.2 and 199.7 cGy for SSD= 95 cm, SSD= 97.5 cm and SSD= 100 cm, respectively, when there was no air gap between the bolus and the surface. When there was a 10 mm air gap between the bolus and the surface, the surface doses were 106.2, 70.6 and 193 cGy, respectively. The dose distributions on the phantom due to three different SSD variations are shown in Fig 2.

For SSD=95, the surface doses for air gap 0, 1, 3, 5 and 10 mm were 199.6, 156.9, 108.4, 106.2 and 104.4 cGy, respectively. For SSD=97.5, the surface doses for air gap 0, 1, 3, 5 and 10 mm were 175.2, 135.2, 96.7, 85.4 and 70.6 cGy, respectively. Point dose measurements showed that surface doses decreased significantly as the gap between the phantom surface and the bolus increased. The effects of the air gap between the phantom surface and the bolus on the dose distribution at different depths are shown in Fig 3, Fig 4 and Fig 5 for SSD= 95, SSD= 97.5 and SSD= 100 cm, respectively.

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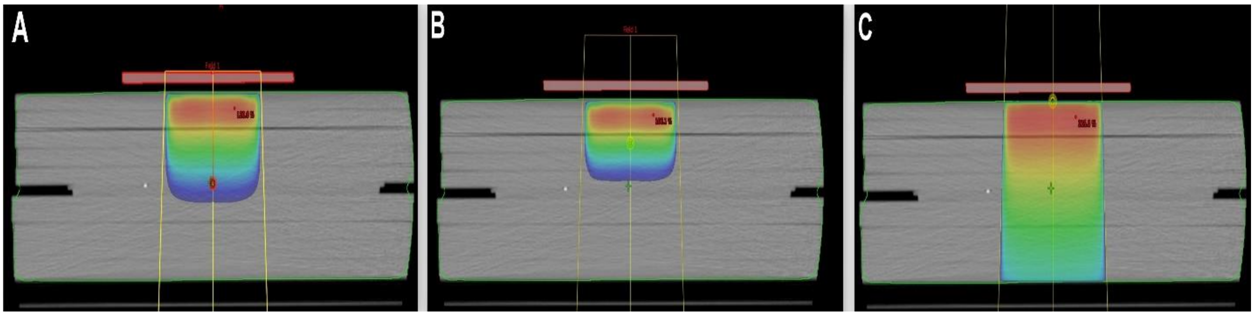

Figure 2. Dose distributions for different SSDs with 5mm air gap between bolus and phantom surface. A: SSD=95cm, B: SSD= 97.5cm and C: SSD= 100cm

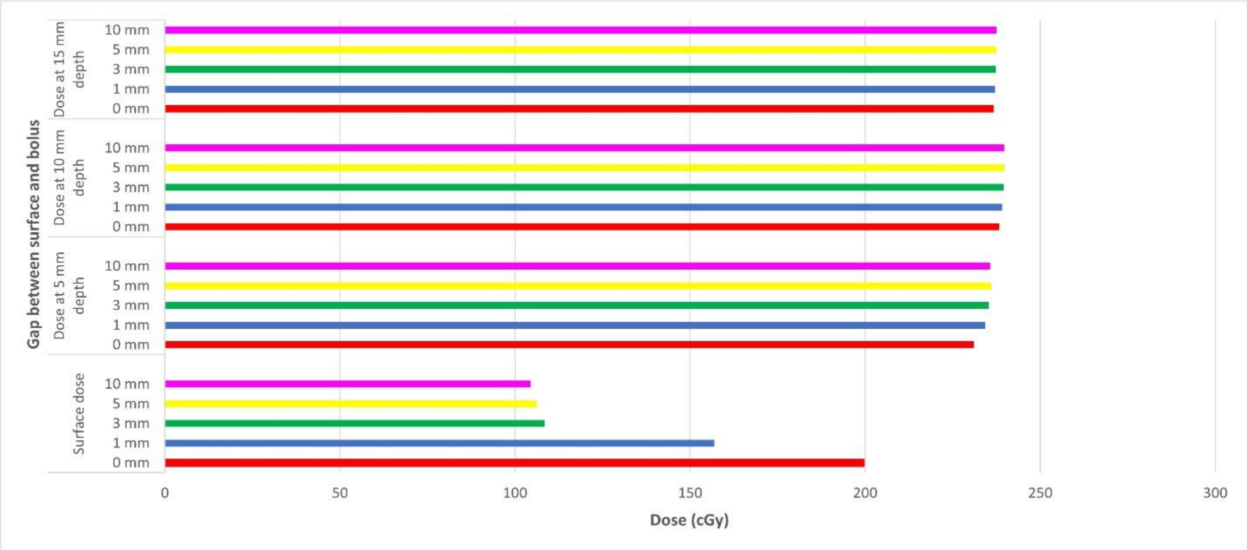

Figure 3. The effect of the air gap on the dose distribution at different depths for SSD= 95 cm as a result of calculations made on TPS.

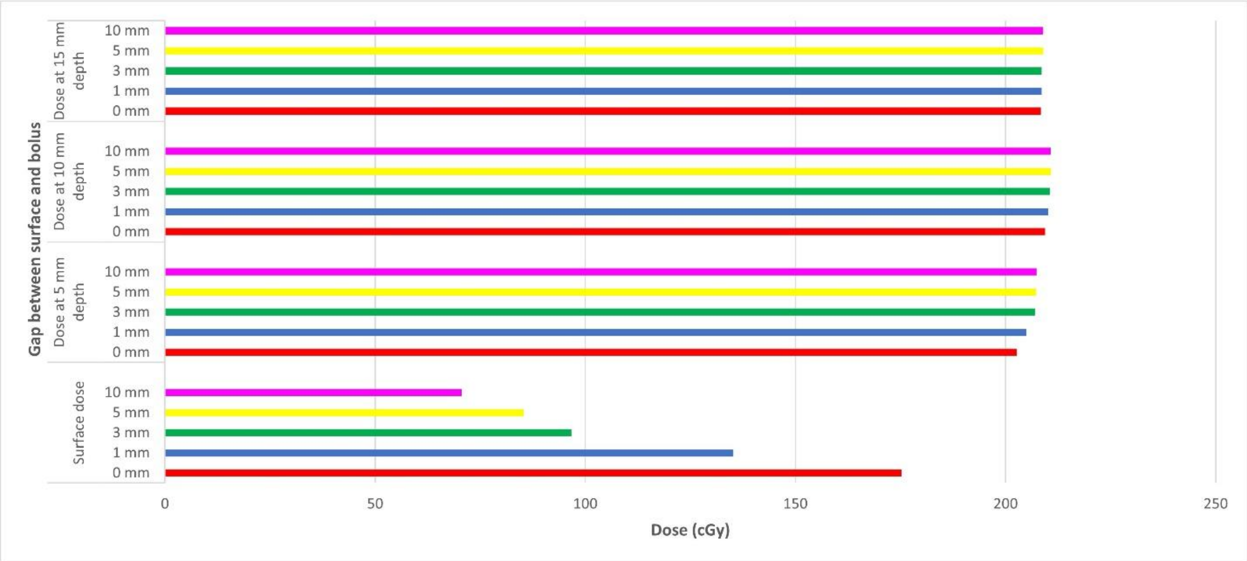

Figure 4. The effect of the air gap on the dose distribution at different depths for SSD=97.5 cm as a result of calculations made on TPS.

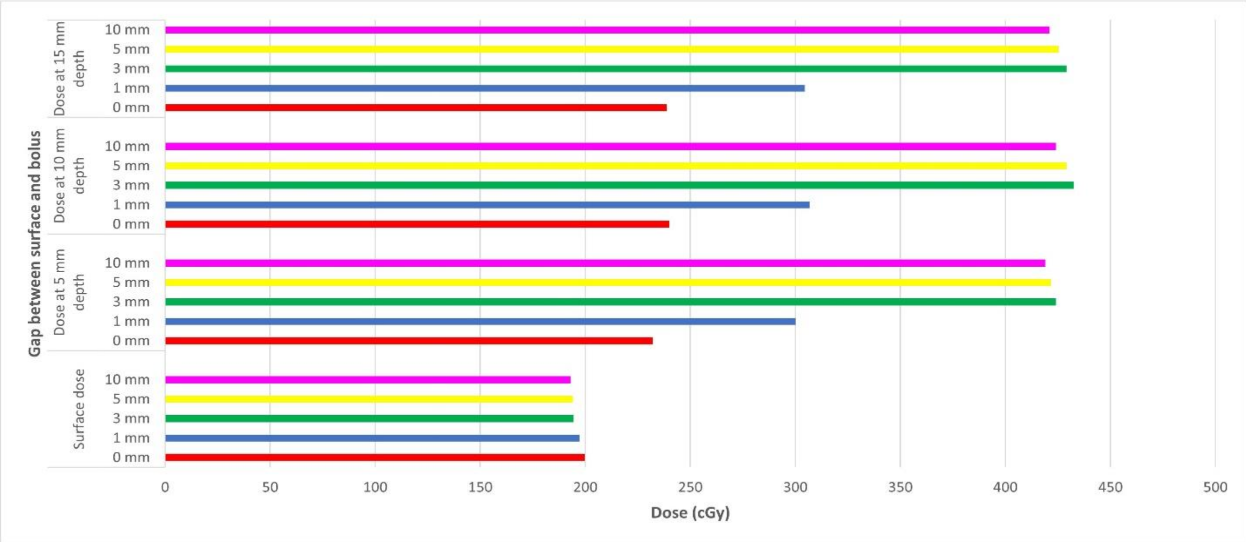

Figure 5. The effect of the air gap on the dose distribution at different depths for SSD=100 cm as a result of calculations made on TPS.

Khan et al. using a 1.0 cm super-flab bolus, investigated the effects of various scenarios of air gaps between the surface and the bolus on dose distribution. They showed that as the distance between the bolus and the surface increases, the relative dose decreases [13].

In the current study, dose distributions were investigated at different depths and different SSDs. For SSD= 95 and SSD= 97.5 cm, it was observed that the surface dose decreased as the distance of the gap between the bolus and the surface increased. There was no significant difference between the dose distributions for build-up depth. For SSD=100 cm, the surface dose decreased as the air gap increased, but fluctuations were observed in the calculations by TPS at other depths. Srinivas et al. evaluated dosimetric parameters such as depth dose along the central axis using a 6 MV clinical photon beam in the presence of air gaps between the gel bolus and the treatment surface. They reported that the surface dose decreased as the air gap increased in the presence of a 0.5 cm bolus and a 10x10 cm^2 beam field [14].

In this TPS study, it was found that especially the surface dose decreased with increasing air gap in parallel with Srinivas et al. In a study by Butson et al. using a parallel plate ionization chamber and radiochromic film with 6MV photon beams and 1cm bolus, it was observed that small air spaces between the bolus and the skin reduced the skin dose [15].

In the current study, it was observed that increasing the gap between the surface and bolus decreased the surface dose for different SSDs.

4. Conclusion

In dosimetric literature studies and current research, it has been observed that the air gap between the surface and the bolus reduces the surface dose. The limitation of the study is that it is a TPS-based study. It is recommended that bolus use, especially in curved anatomical regions, should be applied before CT scanning as much as possible. When using bolus material in radiotherapy, it is recommended to be careful not to leave an air gap between the surface and the bolus.

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Author's Contributions

Osman Vefa Gül: Drafted and wrote the manuscript, supervised the progress of the experiment, and performed the experiment and results analysis.

Ethics

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

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