Evaluation of Dosimetric Characterization of Homemade Bolus for Radiation Therapy

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Abstract. The bolus is also known a tissue compensation that has material similar to body tissue and placed directly onto the skin surface for radiation therapy. This study aims to characterize and evaluate the synthesized homemade bolus using Natural Rubber, Paraffin Candle, Play-Doh, and Paraffin Wax Pure for radiation therapy using a photon beam. Several dosimetry properties of the synthesized of the bolus, including relative electron density (RED), transmission factor, attenuation coefficient, and percentage of surface dose (PSD), were investigated. All the synthesized bolus material is in accordance with the provisions of bolus as a tissue compensation of the human body, which is almost the same as the value of HU in breast organs, skin, fat and adult bones. Large transmission factors and attenuation coefficients of each bolus correspond to bolus from paraffin candles as the default bolus of the hospital. The maximum bolus dose value increases when compared to measurements without bolus.

1. Introduction
Radiation is an electromagnetic wave and charged particles capable of ionizing the passing medium. One function of radiation is to kill tumor cells. Radiotherapy is medical treatment with ion radiation. One of the radiotherapy media is Cobalt and Linac machines. The radiation source used uses ionizing radiation (x-rays and gamma rays) and other particles. In its development many radiotherapy devices have been created to support this treatment. So that radiotherapy is important in helping sufferers to recover and improve their quality of life [1]. One of the Radiotherapy devices is Linac. Linac has photon & electron energy. During therapy, it is necessary to pay attention to the dose to the target [2]. Examples of cases are laryngeal cancer affecting the spinal cord or eyes. the problem is how to make the dose not penetrate into it. One protective device is bolus. Bolus is a compensation medium for body tissue to increase the dose to the surface and protect the organs at risk. Bolus has been developed by several researchers made from various types of elements, for example Nagata et al to discuss superflab, beeswax [3]. Supratman et al make a sbolus with natural ingredients, namely natural rubber [4]. And In MRCCC Hospital, we use plasticine as a bolus. Therefore this study aims to characterize
and evaluate the synthesized homemade bolus using Natural Rubber, Paraffin Wax, Play-Doh, and Plasticine for radiation therapy using a photon beam.

2. Material and Method

2.1 Fabrication
Bolus for this research has the basic ingredients namely Plasticine, Play-Doh, Parrafin Wax and Natural Rubber. Boluses that have been fabricated and ready to use are Plasticine, Play Doh and Parrafin wax. Especially natural rubber bolus must be processed first by mixing liquid natural rubber with formic acid. The dose for liquid natural rubber is 195 ml with formic acid of 5 ml mixed and immediately stirred for 5 seconds and poured into a mold. For the treatment of bolus plasticine, play-doh is immediately shaped according to the mold. For bolus paraffin wax, it is formed by melting it first. All boluses use the same size of acrylic mold with dimensions 11 × 11 × 1 cm³. The result is a bolus has a thickness of 1 cm and is square in shaped.

2.2 Density Test
Density test is done by taking bolus tomographic images using CT Scan which will be performed at the radiotherapy installation of MRCCC Hospital Siloam Semanggi Jakarta. The bolus tomographic image capture method uses axial scanning method with the tube voltage and current used at 120 kV and 160 mA. The results of the tomographic images on the bolus are sent to the computer so they can read the CT-Number values in the Treatment Planning System (TPS) program. CT-Number retrieval on axial bolus images by making the region of interest (ROI) area of 3 regions in square form. ROI laying is done by positioning the sample in the axial direction. For each variation of 1 bolus, take the ROI point across the 3 points with coordinates. After getting the ROI value, the measurement table appears in Point Tools. The value of Relative Electron Density bolus at each ROI point is obtained. And calculated the average value for the variation of these 3 placement points.

![Figure 1. Display of bolus scanning and table of Point Tools monitors.](image)

2.3 Dosimetry Test
Then the simulation process with Eclipse Software with Treatment Planning System for measuring PDD curves. The first process is by creating a virtual phantom with a height and width of 40 cm. Adjust radiation irradiation using 6 and 10 MV photon energy source. And determine the Reference Point according to the maximum dose depth values of 1.5 and 2 cm. If the 6 MV energy bolus irradiation uses a 1.5 cm reference point, then the 10 MV energy bolus irradiation uses a 2 cm reference point only. then phantom on the surface was given a virtual bolus with an area of 11 x 11 cm². The characteristics of virtual boluses are adjusted to the results of the study boluses by referring to the CT number of each bolus according to the measurement results.

PDD curve results that appear as shown in Figure 2. Then the results of the curve are exported so that the value of each coordinate can be stored for the curve. To get the Surface Dose Percentage value, a percentage value at 0 cm depth is taken for each bolus variation. To get the buildup area
curve, PDD data is reprocessed into graphs with Origin 8 software and limited to a depth of only 3 cm.

![Figure 2. Display of PDD curve results after Eclipse program calculation.](image)

3. Result and Discussion
One of the basic parameters of bolus as a compensatory medium in radiotherapy treatment is that it has properties such as human body tissue. In this study, the bolus material used has the physical appearance of the bolus as shown in Figure 3. With the information bolus A (Plasticine), B (Natural Rubber), C (Paraffin Wax), D (Play-Doh).

![Figure 3. Results from materials that have been made (a) natural rubber (b) paraffin wax (c) Play-Doh](image)

3.1 Density Test
The electron density test process using the Treatment Planning System produces an average RED value from the measurement of the 3-point ROI density for each bolus material. Using references from [5] and [6], each bolus represents a particular organ. Bolus A and D have almost similar texture and composition. Electron density values between the two also have a small difference in difference. However, by following the organ density reference, it is clear that the difference in range for Bolus A and Bolus D. In bolus A has a range of values between the soft organs of the muscles to the liver.
Whereas Bolus D enters tissue in the bone / marrow. Bolus Plasticine and Play-Doh have the same texture and the RED value is almost the same. So that Bolus Play-Doh and Plasticine can be used for the use of superficial cancer therapies that are on the surface of the body with uneven body contours, thus requiring thicker and more flexible boluses so that on the target surface the radiation gets the maximum dose and minimizes the presence of air gap [7]. Reference for (1) K Nobuyuki. 2015. Relationship between mass density, electron density, and elemental composition of body tissues for Monte Carlo simulation in radiation treatment planning (2). S J Thomas, MA, MSc. 1999. Relative electron density calibration of CT scanners for radiotherapy treatment planning.

Table 1. The results of the bolus electron density test results of the study results are adjusted to reference certain organ categories

| Category          | \( \rho_e \) (g/cm\(^3\)) | Ref       | Bolus research results                  |
|-------------------|-----------------------------|-----------|----------------------------------------|
| Air-containing    | 0.79                        | (1)       | Bolus B (natural rubber), Bolus C (paraffin wax) |
| Fat               | 0.907                       | (1), (2)  | Bolus C (paraffin wax)                 |
| Adipose/marrow    | 0.95                        | (1)       | Bolus D (playdoh)                      |
| Muscle/organ      | 1.04                        | (1)       | Bolus A (plasticine)                   |
| Liver             | 1.05                        | (2)       | Bolus A (plasticine)                   |

3.2 Simulation with Eclipse

Overall, for each bolus material it has a different PSD value for each thickness. This is in accordance with previous studies [8] where for each increase in bolus thickness will increase the PSD value. This increase occurs due to differences in scattering (scattering) experienced by each bolus when electron particles pass through a medium (solid slab water phantom). When electrons pass through a medium, they will interact with atoms in the medium. Causing electrons to lose kinetic energy (loss of radiation energy) or change in direction (scattering) [9]. Thus for boluses that are smaller in thickness make electrons more scattering than boluses that have larger thicknesses.

![Figure 4. The results of the percentage surface dose in photon energy](image-url)
The percentage of the surface dose for the 6 MV photon energy is greater than the 10 MV photon energy. In bolus thickness of 1.5 cm with 6 MV energy can reach 100%. This shows the higher the radiation energy used, the percentage of the surface dose without bolus is decreased [10]. This means that in the radiation target surface area, the absorbed dose is the maximum dose. This is recommended for the treatment of cancer that is on the surface of the body [11].

4. Conclusions

Based on the results of research conducted it can be concluded that the value of bolus material density is determined in two kinds, namely physical density and electron density. RED (Relative Electron Density) is obtained from CT Number values with the results showing that all bolus materials such as Natural rubber, paraffin wax, play-doh and plasticine have the same characteristics as organs and commercial boluses. The use of bolus material can increase the percentage of surface dose on all photon energies. At 6 MV photon energy an increase in surface dosage of up to 100% for the plasticine bolus and play-doh material is increased. Then the bolus material can change the build-up area to the surface of the radiation target because of the attenuation of the bolus.

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