The Properties of Bolus Material using Silicone Rubber

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Abstract. Bolus is a material equivalent to tissue and used in radiotherapy process to increase a dose surface using electron beam. The bolus synthesis from a material equivalent to tissue is not easy, one of the alternative materials used is silicone rubber (SR). In this research bolus was synthesized with dimension of length x width x thickness is (17 x 17 x 1) cm³. Bolus has been characterized by CT-Scan to find relative electron density (RED) and linear accelerator (LINAC) to investigate percentage of surface dose (PSD) with two energy (8 MeV and 10 MeV). The RED value for bolus is 1.176, these results show the RED value for bolus between soft tissue and solid tissue. The PSD value at 8 MeV and 10 MeV are 102.32% and 101.32%, respectively. These results indicate that the silicone rubber material can be used as an alternative bolus material because it corresponds to the bolus function in radiotherapy.

Keyword: Bolus, Soft Tissue, Silicone Rubber, Electron Density, Percentage of Surface Dose.

1. Introduction
Bolus is a material equivalent to tissue and used in radiotherapy process [1]. In radiotherapy, bolus has several function such as increasing the surface dose, leveling the body surface of the irregular patient in order to obtain radiation dose uniformity, and reduce a possible electron penetration to soft tissue around the area of cancer [2,3]. Bolus synthesis with material equivalent to tissue is not easy, but some studies have used some materials that are equivalent to the tissue such as parafin granules, elasto-gel pad, superflab, thermoplastic sheets, dental wax, polypropylene, and rayon blend [4-6]. The use of these material as bolus, especially in Indonesia still very limited and must import to be used in radiotherapy. One of the alternative material that can be used for bolus fabrication is silicone rubber (SR).

SR is a synthetic polymer material derived from polydimethyl siloxane (PDMS) [7,8]. SR is easy to find in Indonesia because it is a product derived from petrochemicals. SR has several advantages such as has an excellent level of elasticity at very low temperature, excellent properites against heat, resistance to ultraviolet light, has a high level of resistance with various types irradiation, and low toxicity [9-12]. In addition, SR has been used as radioprotection material in radiotherapy with electron beam and can reduce electron penetration by 42.9% at 6 MeV [13]. In medical field, SR has been used...
to fabrication artificial organs such as rectum, obturator musculus internus and levator ani musculus as a group organ for prostate brachytherapy application [14].

In this work, SR is used as a bolus material because SR has material characteristics similar to tissue. To investigate SR characteristics, some characterizations have been done, among others relative electron density (RED) measurement and percentage of surface dose (PSD) using an electron beam radiation. This characterization is a basic test to show SR material can be used as an alternative bolus material.

2. Materials and Methods

2.1. Materials
Bolus used in this research was synthesized using silicone rubber (SR) RTV-5 and bluesil catalyst 60 R as hardener (Indrasari Chemical Store, Semarang, Indonesia). Bolus dimension (length x width x thickness) is (17 x 17 x 1) cm$^3$. For synthesis process using a simple molded method, which that SR with volume of 28 ml and hardener with volume of 11 ml have been mixed by mixer (Maspion, Indonesia) for 6 minutes. After mixed process, the sample (SR and hardener) poured into wooden cast and wait for the sample to dry completely. Then, sample has been removed from wood mold and wiped by paper, for the result can be seen in Figure 1.

![Figure 1. Bolus from silicone rubber material](image)

2.2. Relative Electron Density Measurement of relative electron density (RED) on bolus by scanning process using CT-Scan (Thosiba, Japan). The scanning method used axial scanning and the tomography image was send to the computer for determine CT-Number. To calculate RED value from CT-Number using equation as follows:

$$\rho_e = 1.052 + 0.00048N_{CT} \quad (1)$$

$$\rho_e = 1.000 + 0.001N_{CT} \quad (2)$$

with $\rho_e$ is electron density and $N_{CT}$ is CT-Number. If the CT-Number is greater than 100 then use an equation (1) and CT-Number less thann 100 using equation (2) [15].

2.3. Percentage of Surface Dose (PSD)
The measurement of the percentage of surface dose (PSD) on the bolus has been done by giving the electron beam radiation from the Linear Accelerator (LINAC) device (Elekta, Sweden). The energy used are 8 MeV and 10 MeV with applicator field of 10 x 10 cm$^2$, and source to surface dose (SSD) has been set up in a position of 100 cm. The plan parallel chamber detector (Iba Dosimetry, Sweden) is used to measure electron beam radiation in surface and depth dose maximum position ($d_{max}$) on solid water phantom shown in Figure 2. For $d_{max}$ value of 8 MeV and 10 MeV is 1.7 cm and 2.2 cm, respectively. The data can read by an electrometer (Iba Dosimetry, Sweden) in units of nanocoulomb (nC). To calculate PSD value using equation as follows:
\[ P_A = \frac{D_S}{D_M} \times 100 \% \]  
\[ P_B = \frac{D_{SB}}{D_M} \times 100 \% \]

with \( P_A \) is PSD value without bolus, \( P_B \) is PSD value using bolus, \( D_S \) is radiation dose measured on the surface of solid water phantom without bolus, \( D_{SB} \) is radiation dose measured on the surface of solid water phantom using bolus, and \( D_M \) is radiation dose measured on a \( d_{max} \) position of solid water phantom without using bolus [2].

**Figure 2.** Schematic to measurement percentage of surface dose (PSD)

3. **Results and Discussion**

3.1. **Relative Electron Density (RED)**

In this results, the relative electron density (RED) from bolus made of silicone rubber (SR) is 1.176, for the RED value of some tissue can be seen in Tabel 1 below.

| Tissue/Material | Relative Electron Density | Reference |
|-----------------|---------------------------|-----------|
| Water           | 1.000                     | [16]      |
| Muscle          | 1.043                     | [16]      |
| Breast          | 0.976                     | [17]      |
| Dense Bone      | 1.512                     | [17]      |

Based on Table 1, the RED produced by the bolus is above the RED value of water and soft tissue such as muscle and breast. This is because of different material compositions between soft tissues and boluses. Soft tissue consists of hydrogen (H), carbon (C), oxygen (O), nitrogen (N), phosphor (P), sulphur (S), chlorine (Cl), and potassium (K) [18,19]. On the other hand, bolus with SR material consists of inorganic polymer bond composed by polysiloxan (Si-O) bonds and methyl (CH3) bonds [20]. When compared with a solid tissue such as dense bone material, the electron density of bolus is below the value of electron density dense bone. If viewed from the composing dense bone material, the dense bone consists of mineral phase, hydroxyapatite (Ca10(PO4)6(OH)2), an organic phase, and water [21]. So it has different material density both with bolus material and soft tissue. When compared with alternative
materials such as ethyl methacrylate [15] and durian seed [17], RED value is much smaller than SR. This is because the two materials have a material composition similar with water. However, the results of this study support the results of research conducted by Li et al [14] who have used SR as an ingredient in prostate group organs synthesis. Thus, SR can be an alternative material that is equivalent to a tissue.

3.2. Relative Electron Density (RED)
For PSD results on solid phantom surface can be seen in Figure 4. Based on Figure 4, the PSD value without using bolus on 8 MeV and 10 MeV are 89.18% and 90.55%, respectively. At the time of using bolus, the PSD value for 8 MeV and 10 MeV has increased to 102.32% and 101.32%, respectively. These results indicate the use of bolus with SR material can provide an increase in PSD value with a percentage above 100%, when using radiation energy greater than 8 MeV, the value of PSD was decreased. Supposedly, a greater radiation energy can increase the value of PSD [1]. This is because the amount of radiation energy can provide an increase in kinetic energy of electron particles so that electrons can penetrate deeper solid water phantom. When compared with elasto gel, the resulting PSD value is 98.2% at 9 MeV with a thickness of 1.25 cm [2]. This result shows that SR with a thickness of 1 cm can provide a higher PSD value than using elasto gel. However, based on the aim of used a bolus, bolus with SR material has been succeeded in increasing PSD value on solid water phantom surface. The use of SR can be an alternative material that can be used as a bolus. For the future, a further research is needed to investigate of varying composition between SR and hardener to measure an RED and PSD for each composition variation.

![Figure 3. Percentage of surface dose (PSD) graph](image)

4. Conclusion
Based on the results of this research, bolus with silicone rubber material has electron density value of 1.176. These results show the value of RED bolus between soft tissue and solid tissue. The PSD value at 8 MeV and 10 MeV are 102.32% and 101.32%, respectively. These results indicate that the silicone rubber material can be used as an alternative bolus material because it corresponds to the bolus function in radiotherapy.

5. Conclusion
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