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Fabrication of Bolus from Composite of Silicone Rubber (SR) - Copper (Cu) for Radiotherapy Application

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Abstract: ***Bolus is used for therapeutic purposes in order to increase the dose to be received in cancer on the surface of the skin. In this research, the ingredients of bolus made of Silicone Rubber (SR) with an additional copper (Cu). The purpose of this study was to characterize the density, relative electron density (RED) and surface doses of boluses. Bolus is made with a thickness of 0.5 cm and a variation of weight percent (wt%) of 0 wt%, 6 wt%, 8 wt% and 10 wt% for samples A, B, C and D, respectively. Synthesis of SR-Cu bolus samples was carried out by the chemical solution deposition method. Bolus printed with dimensions $17 \times 17 \times 0.5\ cm^3$. Bolus is illuminated using electron beams from Linac with an energy of 8 MeV. The calculation results show that bolus density approaches the density value of soft tissue, with the highest density in sample A and the lowest in sample B. Overall the use of this bolus can increase the surface dose. At energy of 8 MeV, the highest percentage of surface dose was in sample D, while the lowest in sample A. The elasticity test of the sample was carried out using ASTM D638M-64 with the highest modulus young value in sample A and the lowest in sample B. The elasticity calculation results showed that all bolus samples with the addition of Cu powder will become more elastic. Bolus made from SR-Cu can be used as an alternative material for radiotherapy.***

Keywords: Bolus**,** Silicone Rubber (SR)**,** Copper (Cu)**,** Radiotherapy

1. Introduction

Cancer is a high cause of death in this world, around 7.6 million people died due to cancer [1]. Cancer is a disease caused by abnormal cell growth [2]. Cancer treatment can be done through surgery, chemotherapy and radiation therapy. Radiation therapy or radiotherapy is one of the methods of cancer treatment using ionizing radiation [3, 4]. Linear Accelerator (Linac) is one of the devices producing ionizing radiation beams that produce high-energy photons and electrons. The electron beam used in this Linear Accelerator has an energy range of around 4 to 25 MeV [5].

Bolus is a material equivalent to tissue placed directly on the surface of the skin to flatten the irregular contours of the patient so that it can provide a flat surface to facilitate the radiation process in radiotherapy [5, 6]. Bolus has the main function of increasing the surface dose, giving a flat effect on the uneven surface of the patient, reducing damage to healthy tissue around the area of skin cancer and reducing electron penetration that is likely to affect healthy tissue [7, 8]. In cancer therapy, the percentage of the dose on the surface of the skin is not close to 100% so that accurate techniques are needed to increase the dose. One technique for increasing surface doses is to use boluses [9]. Boluses that are often used have thickness (0.5-1.5 cm), because they do not significantly change the shape of the isodose curve at depth [5].

Silicone rubber (SR) is used as an alternative material because it is easily found in Indonesia and has several advantages such as being able to accurately shape the patient's body parts, non-toxic, non-irritating to the surface of the skin and can increase the surface dose of the skin [4, 10, 11]

The aim of addition of copper to silicone rubber is to increase bolus density. The use of high density material can increase the surface dose so that it can optimize the process of radiotherapy for the treatment of skin cancer [12]. Addition of copper to bolus material made from silicon rubber will also cause the bolus to have a thinner thickness closer to the recommended thickness [5]. This research is intended to find out the increase in absorbency dose and radiation protection value of bolus made from silicon rubber with copper added.

2. Literature Survey

In the treatment of skin surface cancer (with a depth of less than 5 cm) can be done using an electron beam [13]. The electron beam is used for superficial skin cancer because the electron beam in this Linear Accelerator has an energy range of around 4 to 25 MeV and has a lower penetration power than the photon beam [5]. In electron beam therapy, the percentage of the dose on superficial skin is not close to 100% so that accurate techniques are needed to increase the dose. One technique for increasing surface doses is to use boluses [14,9]

Some materials that have been used as boluses in radiotherapy include elasto-gel, high absorbent polypropylene and rayon colth (HAPRC), superflab, wet towel, and wet gauze [15,16,17,18]. The use of HAPRC as a bolus is less effective because it is only used once for one patient, making it less practical to use. Meanwhile, elasto-gel boluses require high manufacturing costs due to the limited availability of materials in Indonesia, so they must be adopted first. The use of wet towels and wet gauze as boluses has a weakness in the form of an uneven dose distribution, while boluses made from superflab are less flexible so they are not suitable when applied to the patient's body [15, 16, 17, 18]. So that alternative materials are needed for the manufacture of bolus.

In this research, silicone rubber (SR) is used as an alternative material for bolus because it is easily found in Indonesia. The use of SR as a bolus made with a thickness of 1 cm has been shown to increase the percentage of surface dose to above 100% for 8 and 10 MeV energies [19]. Addition of copper to silicone rubber (SR) can be used as a shield from high-energy electrons during the therapy prosess so that it can protect healthy tissue [20]

3. Method

Bolus in this study consisted of silicone rubber-RTV 52 (CV. Indrasari, Semarang), copper powder (Natura Product Ltd, Novosibirk, Russia), catalysts as hardener (BluesilCatalys 60R) (CV. Indrasari, Semarang) and PEG 4000 (CV Equipment Kit, Semarang, Indonesia). Bolus is made from variations of silicone rubber and variations of copper powder (Cu) 6 wt%, 8 wt% and 10 wt% with dimensions of $17 \times 17 \times 0.5\, cm^3$.Bolus manufacturing is carried out in two stages, namely the manufacture of PEG-Cu solution and SR-Cu mixing. The bolus synthesis process can be seen in Figure 1, and the synthesis results are shown in Figure 2.

3.1 Calculation of Bolus Density

The mass of each sample is measured using a digital balance (ACS / AD 300) and the sample volume is obtained by calculating the bolus dimensions. The density of each bolus sample is calculated by known mass and volume.[21].

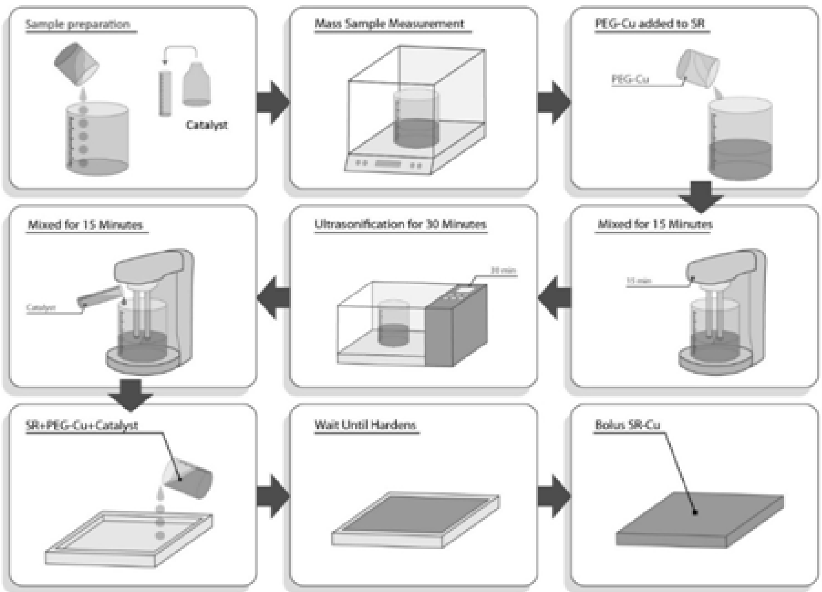

Figure 1: Schematic of bolus production made from SR-Cu

3.2 Testing of Relative Electron Density (RED)

Electron density testing is obtained by taking bolus tomographic images using CT-SCAN, then sent to the TPS. Bolus tomographic images were taken in axial direction of 10 values (using the axial scanning method) at the voltage of 120 kV and the tube current of 160 mA.The CT-number obtained is used to find the relative electron density value using equation 1 and 2

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

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

With ρ_a is a relative electron density with a CT-Number value greater than 100, ρ_b is a relative electron density value with a CT-Number value of less than 100, and N_{CT} is CT-*Number* [22].

3.3 Testing of Percentage Surface Dose (PSD)

Testing of Percentage Surface Dose on bolus is carried out by providing electron radiation produced by Linear Accelerator (LINAC Siemens / Primus M class 5633). The electron beam used is 8 MeV with the application field. Source Distance Dose (SDD) is set in a position of 100 cm. Retrieval of radiation data is done by placing a parallel chamber detector plan on the surface and at the maximum dose depth (D_{max}) on the solid phantom. D_{max} value for the 8 MeV energy is 1.7 cm. PSD is calculated using equation 3.

$$\%PSD = \frac{D_s}{D_{max}} \times 100\% \quad (3)$$

D_s is the radiation dose measured on the solid surface of the phantom and D_{maks} is the dose measured at the maximum depth of the solid phantom [23].

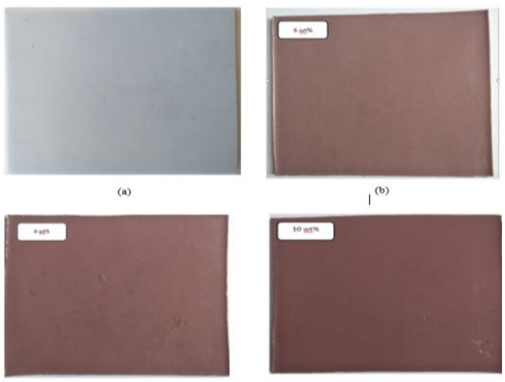

Figure 2: Synthesis of bolus SR with variations in Cu powder (a) 0 wt% (b) 6 wt%, (c) 8 wt% and (d) 10 wt%

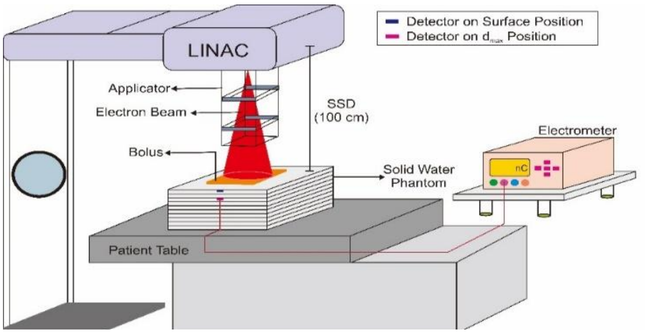

Figure 3: Schematic data collection using bolus

4. Results

4.1 Bolus Density

In this study, the density is calculated on Cu powder variation of 0wt%, 6wt%, 8wt%, and 10wt%. The results of the bolus density calculation can be seen in Figure 4. Each sample has a different density. Samples with the highest Cu powder (10wt%) produce the greatest density, while samples with Cu powder of 0 wt% produce the smallest density. The difference in addition of Cu powder affects bolus density [12].

The results of bolus density of each sample that has been made has the same density with the average value of soft tissue, 1 gr/cm3 so that it is in accordance with one of the factors using the material as bolus [24]. Based on the reference data the bolus sample is made close to the value of muscle soft tissue [25].

4.2 Relative Electron Density

The bolus sample RED value is obtained by processing the tomographic image data of each data at the TPS so that the CT-Number value is obtained. The CT-Number value obtained is above 100 so that the calculation of the RED value uses equation 1. The results of the calculation of the RED value are shown in Figure 5. The results of the study indicate that the more use of composite materials (eg. Cu powder), the RED value will increase [26]. Table 1 presents the RED values of several types of networks as follows:

Based on Table 1, the RED value of each sample has a value above the soft tissue. The difference in the RED value is due to differences in the material composition between soft tissue and bolus samples. Soft tissue is composed of elements such as carbon (C), nitrogen (N), hydrogen (H), potassium (K), sulfur (S), clorin (Cl) and phosphorus (P) [26]. Whereas the bolus sample material (SR) is composed of repeating polymer chains and consists of silicon ligands and organic components. SR has a chemical symbol (C2H6OSi) [27]. The addition of Cu powder to SR bolus samples caused an increase in RED values. Materials that have a higher density have an arrangement of atoms that are close together and each atom carries an electric charge and has a greater electron density thereby increasing the RED value.

Table 1: Relative electron density of various types of tissue [28, 29]

Type	Tissue	Relative electron density
Soft	Lungs	0,26
Soft	Fat	0,95
Soft	Breast	0,98
Soft	Muscle	1,04
Soft	Liver	1,05
Solid	Solid bone	1,51

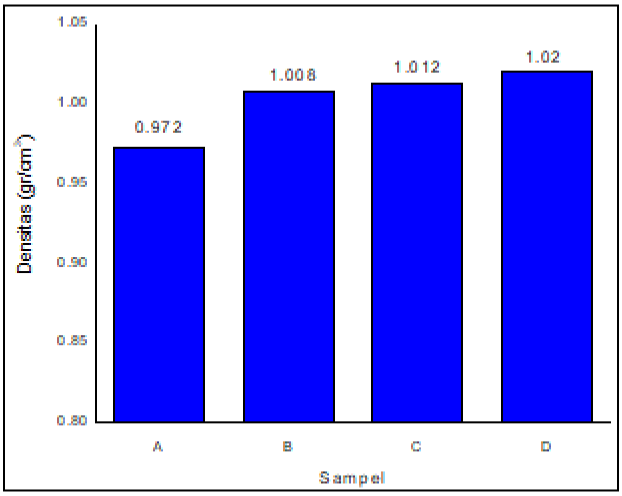

Figure 4: Graph of density of each sample

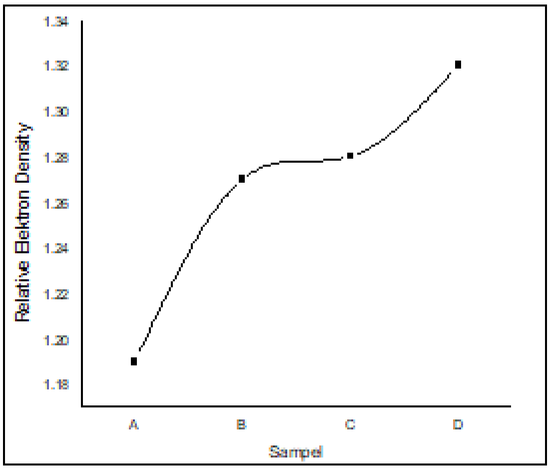

Figure 5: Relative electron densities of each sample

4.3 Percentage Surface Dose (PSD)

The results of PSD calculations on solid phantom surfaces can be seen in Figure 6. It can be seen that each SR-Cu bolus sample shows an increase in PSD value. The PSD value without using a bolus at 8 MeV energy is 85.99%. After using the bolus it increased to 95.03%, 95.12%, 95.48% and 95.66%. The biggest increase in PSD value at 8 MeV energy was produced by sample D and the smallest is sample A.

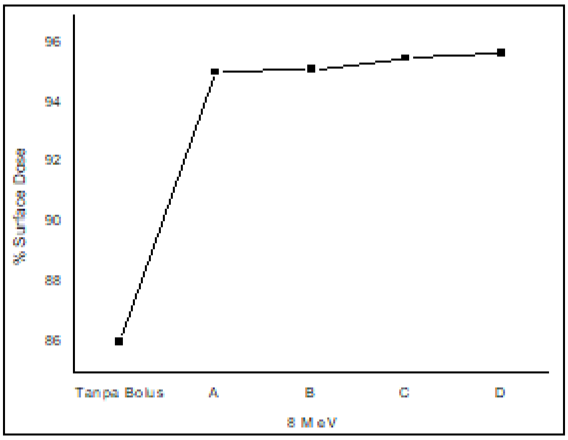

Figure 6: Percentage of Surface Dose (PSD) on a solid phantom surface

Figure 6 shows that the use of bolus can increase the PSD value on the solid surface of phantom. This is caused by a shift in the buildup area that approaches the solid surface of the phantom. Buildup is the area between the surface of the skin and its position in D_{max}. [5,23]. Overall the results of this study approach the research conducted by Gunham et al 2003 and Jaya et al 2018 [18,11]. When boluses are irradiated using electron beams produced by Linac, increasing the dose in the target area (tumor or cancer) can be maximized at a depth of less than 5 cm from the surface of the skin.

4.4 Bolus Elasticity

Bolus elasticity calculations were performed using the ASTM D638M-64. The elasticity value of each sample can be seen in Figure 7. Each sample has a different elasticity value. Young modulus values of the samples were 0.86 MPa, 0.34 MPa, 0.37 MPa and 0.36 MPa, respectively. Samples without Cu powder (0 wt%) produced the greatest modulus of young, while samples with Cu powder of 2 wt% produced the lowest modulus young. The difference in addition of Cu powder influences the modulus value of young bolus samples.Young modulus of each bolus sample that has been made has a value below 100 MPa so that it fulfills one of the factors in choosing a material as bolus, it’s elastic [30].

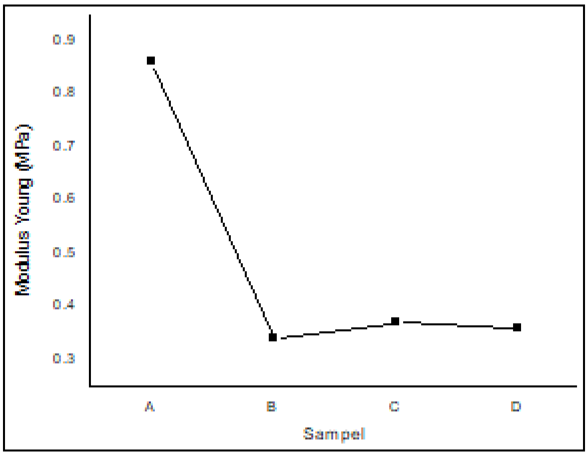

Figure 7: Modulus young values of each sample

5. Conclusion

Bolus synthesis made from SR with variations in Cu powder addition was successfully carried out using the cemical solution deposition method. Samples that have been made are analyzed density, relative value of electron density and PSD value. All bolus sample densities approach the true soft tissue values. Overall the use of bolus can increase the surface dose and elasticity. Based on these results, it can be concluded that the SR-Cu bolus material can be used as an alternative bolus material for radiotherapy purposes.

6. Future Scope

The bolus research with SR material added with Cu needs to be continued with increase the concentration of copper composite at a larger SR than this study to obtain a larger increase in surface dose, variation of bolus thickness to get the PDD curve for further research reference.

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