

Comparison of Absorbed Dose in Plasticine Bolus and Silicone Rubber Bolus

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Abstract: Bolus is a radiotherapy device used to increase the surface dose in the skin surface area when using electron or photon beams. The most commonly used bolus is a bolus made from plasticine, in addition to a plasticine bolus there is also a bolus made from silicone rubber which is currently being developed. This study aims to determine which bolus is more effectively used in radiotherapy, by comparing the absorbed dose, the value of Relative Electron Density (RED), and the transmission factor of each bolus. In this study, silicone rubber and plasticine boluses were made with dimensions of 12 cm x 12 cm, the variation of energy used in LINAC was 9 MeV and 12 MeV and the thickness variation of each bolus was 0.5 cm, 1.0 cm, 1.5 cm and 2.0 cm. The RED value obtained from the plasticine bolus for a thickness of 0.5 cm is 0.837 g/cm³, a thickness of 1.0 cm is 1.011 g/cm³, a thickness of 1.5 cm is 1.06 g/cm³, and a thickness of 2.0 cm of 1.072 g/cm³, while for silicone rubber bolus for a thickness of 0.5 cm is 1.146 g/cm³, a thickness of 1.0 cm is 1.151 g/cm³, a thickness of 1.5 cm is 1.17 g/cm³, and a thickness of 2.0 cm is 1.193 g/cm³. From the results of the study for the RED value of each bolus, it can be concluded that the silicone rubber bolus has a RED value that is more consistent with the water density value compared to the plasticine bolus. Silicone rubber and plasticine boluses can also be said to be absorbent materials because the transmission factor value of both boluses is below 100%. From the results of the study, silicone rubber boluses were more able to reduce the range of absorbed doses compared to plasticine boluses.

Keywords: Bolus, LINAC, radiotheraph, relative electron density, silicone rubber.

1. Introduction

Gamma radiation (γ) is ionizing radiation that can form ions and store the energy it produces in the tissue cells it passes through. The energy is capable of destroying the tissue it is exposed to, both normal and abnormal tissue. Giving the right dose plays an important role in shooting gamma radiation on target tissues such as tumors and cancer so that it will not damage surrounding healthy tissue (Astuti et al, 2018).

In general, all cancers can be treated using radiotherapy because cancer cells are very sensitive to radiation (Susworo, 2007). Radiotherapy or radiation therapy is a method of treating cancer using ionizing rays such as gamma rays. The dose given during radiotherapy is very high so that initial planning before carrying out treatment needs to be considered so that the dose received is optimal and does not damage healthy tissue. The purpose of radiotherapy is to stop the growth and spread of cancer and to kill the cancer cells. Radiotherapy based on the way the radiation is delivered is divided into two ways, namely brachytherapy and external radiotherapy. Brachytherapy is a method where the radiation source is placed directly on cancer cells, while external radiotherapy is radiation that is exposed to the patient's body with the help of radiotherapy instrumentation such as Cobalt-60 and LINAC.

Linear accelerator (LINAC) is the most commonly used device for external radiotherapy treatment for cancer patients. LINAC uses microwave technology to accelerate electrons and allows electrons to collide with heavy metal targets to produce high-energy X-rays. The use of LINAC as an external radiotherapy device requires precise dosage so that the radiation beam hitting normal tissue does not damage it and will not cause new cancers to appear in the patient. The amount of dose administered depends on the radiation beam and the position of the cancer being measured such as on the surface of the skin. So far, the treatment of cancer on the skin surface has not reached 100% of the radiation beam dose using LINAC (Junaedi et al, 2016).

Bolus is a radiotherapy device that is used to increase the surface dose in the skin surface area and reduce the depth dose when using electron or photon beams. Bolus-making materials are similar to soft tissue properties in stopping power and scattering power placed on the skin surface during radiotherapy (Podgorsak, 2005; Guswantoro et al, 2020). The use of boluses also aims to flatten the patient's body surface which allows uniform surface dose distribution, reduces damage to normal tissue due to radiation that does not only hit the target, and reduces the penetrating power of the radiation beam to normal tissue around the skin cancer area (Sutanto et al, 2018).

The bolus used should have several characteristics including good elasticity, the absence of air bubbles on the surface of the bolus, when radiation is irradiated, it does not change shape and is also non-toxic. At this time, research on bolus materials continues to be developed using various materials such as natural rubber, superflab, plasticine, play-doh, paraffin wax, and silicone rubber (Endarko et al, 2020; Aras et al, 2020; Carina et al, 2020). The most commonly used bolus is a bolus made of plasticine, but this bolus has a rigid structure that can cause an air gap and is difficult to return to its original shape if pressed (Junaedi et al, 2016).

Silicone rubber material in the medical field has been applied in the manufacture of artificial rectum organs (Li et al, 2015). Silicone rubber bolus is composed of silicone material which is more flexible than other polymers, has high water repellent properties, has high dielectric properties, has a high level of elasticity, has good heat resistance, and also has UV resistance. (Sutanto et al, 2018). Therefore, a bolus made of silicone rubber can be used as a substitute for a plasticine bolus or other boluses.

This study aims to make a bolus using plasticine and silicone rubber materials, and analyze the absorbed dose using a bolus from an electron radiation beam. Absorbed dose test using parallel chamber plan and LINAC instrumentation. This study also looked at the effect of the absorbed dose with the optimization of radiation energy on the bolus material.

2. Experimental

2.1. Synthetic Bolus Silicone Rubber

The first stage of this research is the synthetic silicone rubber bolus, starting with preparing the tools and materials to be used, such as 17 cm x 17 cm acrylic, 500 ml and 10 ml plastic measuring cups, mixer, silicone oil, brush, and spatula. The material that will be used to make this bolus is silicone rubber RTV-52, to speed up the hardening process of the silicone rubber material, an RTV catalyst is used as a catalyst. The silicone rubber bolus to be made has dimensions of 17 cm x 17 cm with variations in thickness of 0.5 cm, 1 cm, 1.5 cm and 2 cm. The first thing to do is make a bolus print out of acrylic. Furthermore, the mold is coated with silicone oil so that the bolus can be cheaply removed from the mold, then the volume ratio between the silicone rubber and the catalyst is calculated, so that the silicone rubber volume is 278 ml and the catalyst volume is 11 ml. The last step is to pour silicone rubber into a 500 ml measuring cup and the catalyst into a 10 ml measuring cup according to the volume of silicone rubber and catalyst. The mixing process using a mixer is carried out for approximately 6 minutes. The mixing process was carried out by the sol-gel method. The results of the mixing are poured into an acrylic mold that has been smeared with silicone oil. The sample will be allowed to stand for approximately 2 days so that the bolus hardens optimally throughout the area. After drying the sample will be removed from the mold and ready for testing. The manufacturing scheme can be seen in Figure 1.

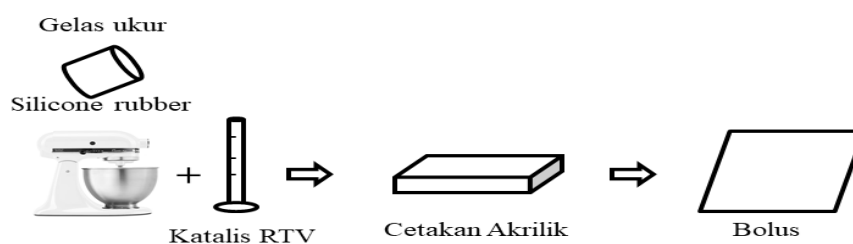


Figure 1. Schematic of making silicone rubber boluses

2.2. Synthetic Bolus Plastisin

In the manufacture of boluses made from plasticine, the main material used is toy plasticine, then palm oil is used to grease the plasticine to make it easier to print it into a mold with dimensions of 17 cm x 17 cm with a thickness of 0.5 cm, 1.0 cm, 1.5 cm and 2.0 cm. All the plasticines are combined, then leveled so that there is no space between the plasticines. The plasticine is put into a mold that has been smeared with palm oil, after the plasticine has been successfully printed, the plasticine is removed from the mold and

wrapped in plastic wrapping. The scheme of making a plasticine bolus can be seen in Figure 2.

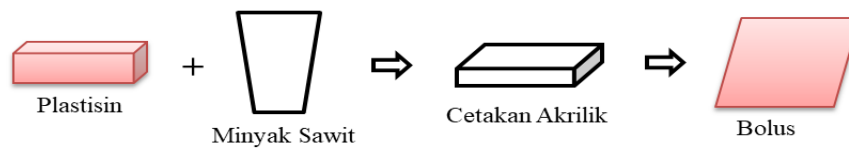


Figure 2. Schematic of Making Plasticine Bolus

2.3. Determining the Relative Electron Density (RED) Value

The bolus to be tested is a bolus made of silicone rubber and a bolus made of plasticine. The first step that must be done is to take tomographic images of silicone rubber boluses and plasticine boluses using a CT-Scan with the method used is the axial scanning method, the voltage and current of the tube to be used is 120 kV and 200 mA and using a PC40 electron detector. After the tomographic image results are obtained, the next step is to create a region of interest (ROI) as many as 5 circular areas with an ROI area of 37.1 mm² to get the CT-Number value. This CT-Number value will be useful for finding the RED bolus value using the following equation:

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

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

Where, N_{CT} is the value of the CT-Number, ρ_a is used for RED whose CT-Number value is greater than 100, while ρ_b is for RED whose CT-Number value is less than 100 (Sutanto et al, 2018).

2.4. Dosimetry Test

The dosimetry test was carried out using electrons with energies of 9 Mev and 12 Mev at a depth of 2.1 cm and 3.0 cm. Measurements were carried out twice using a plan parallel chamber detector and calculated according to the TRS 398 standard to obtain the absorbed dose value. The absorbed dose will be used to calculate the transmission factor and mass attenuation. Measurement of the bolus transmission factor using a parallel chamber plan, where for each measurement, the ionization chamber will be placed at the maximum depth and the bolus will be placed on top of the phantom. The transmission factor can be calculated using the equation:

$$Transmission\ sample\ (100\%) = 100 \times \frac{(Dose\ sample)}{(Dose\ open\ field)} \quad (3)$$

Where, the sample dose is the dose when using a bolus, and the Open Field dose is the dose without a bolus (Endarko et al, 2020).

2.5. Determining the Absorbed Dose

The fourth stage is to determine the percentage value of the absorbed dose using LINAC, solid water phantom, plan parallel chamber detector and using an applicator with

a field area of 10 cm x 10 cm. The first step that must be done is to adjust the source to surface dose (SSD) between the radiation source and the position of the solid water phantom surface at a distance of 100 cm with a mechanical pointer. The electron beam energies from LINAC are 9 MeV and 12 MeV, respectively. Measurement of radiation data was carried out first without using a bolus by placing the detector at the maximum dose depth on the solid phantom, then irradiating it using 9 MeV and 12 MeV energies. The next measurement uses a plasticine bolus and a silicone rubber bolus, where the bolus will be placed on the surface of a solid water phantom that has a detector, then irradiated and the same measurements are taken when measuring without using a bolus. The measurement results from the detector will read the charge value displayed on the electrometer in Gray (Gy) units.

3. Results and Discussion

3.1. Results of Synthesis of Bolus Silicone Rubber



Figure 3. Silicone rubber boluses with various thicknesses (0.5 cm, 1 cm, 1.5 cm, and 2 cm)

Figure 3 shows the results of silicone rubber boluses with variations in thickness. For each thickness of the bolus, a silicone rubber bolus was produced with a flat surface and no air bubbles. Making boluses with silicone rubber material is easy to apply, because the silicone rubber material is liquid, which is easy to print and the hardening process does not take a long time. Silicone rubber bolus material has more flexible properties which is included in the type of polydimethylsiloxane (siloxane inorganic polymer). The constituent elements of siloxane inorganic polymeric bonds consist of silicon (Si), oxygen (O) atoms, and methyl bonds consisting of hydrogen (H) and carbon (C) atoms (Segura and Burillo, 2013). In the silicone rubber bolus, the relative electron density value was found to be equivalent to muscle tissue to bone, where the density value for muscle tissue to bone starts from 1.043 cm/g³ to 1.512 cm/g³ (Endarko et al, 2020).

3.2. Plasticine Bolus Synthesis Results



Figure 4. Plasticine boluses with various thicknesses (0.5 cm, 1 cm, 1.5 cm, and 2 cm)

Figure 4 shows the results of making plasticine boluses with variations in thickness. For each thickness of the bolus, a plasticine bolus with a flat surface is produced as well as a silicone rubber bolus, but because plasticine has a dense and rigid material, air bubbles are still present in the plasticine bolus. Plasticine itself is a compound made from mixing water, dyes, surfactants, lubricants, salts, starch-based binders, humectants, fragrances, and retrogradation inhibitors (Plurality, 2020). In the plasticine bolus, the relative electron density value was found to be equivalent to chest tissue to muscle, where the density value for chest tissue to muscle started from 0.976 cm/g³ to 1.043 cm/g³ (Endarko et al, 2020).

3.3. Dosimetry Test of Silicone Rubber and Plasticine Bolus

The transmission factor was obtained when the sample dose or the dose when using the bolus was compared to the dose without using the bolus. Measurements to obtain this transmission factor were carried out by irradiating using the LINAC instrumentation at an energy of 9 MeV and 12 MeV, where the d_{max} values for each energy were 2.1 cm and 3 cm. The transmission factor is obtained by entering the absorbed dose value into equation (3), the transmission factor for silicone rubber boluses and plasticine boluses with thickness variations of 0.5 cm, 1.0 cm, 1.5 cm, and 2.0 cm can be seen in Fig. Figure 5.

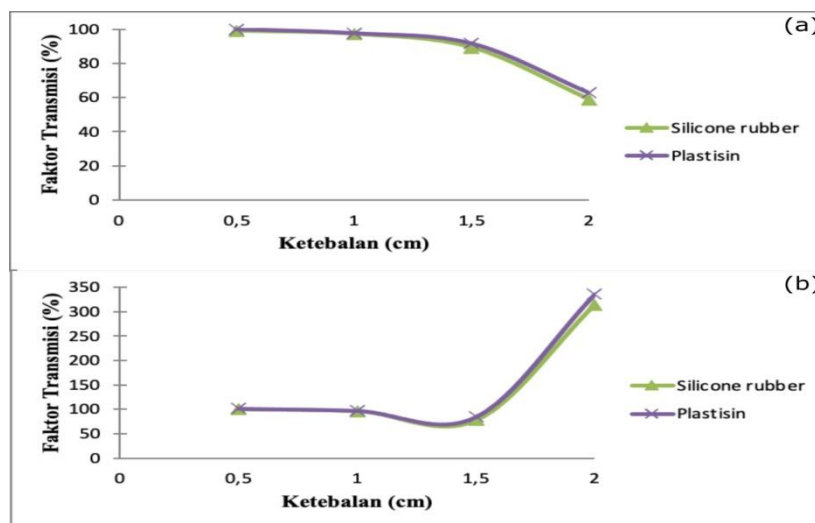


Figure 5. Transmission factor of silicone rubber bolus and plasticine bolus (a) 12 MeV energy, (b) 9 MeV energy

In the research results shown in Figure 5 (a) it can be seen that the results of the study match the theory for an energy of 12 MeV, where a thick bolus has a small transmission factor value. Meanwhile, for the 9 MeV energy in the bolus made of silicone rubber and plasticine with a thickness of 2.0 cm as shown in Figure 5 (b), the value of the transmission factor increases, this occurs because the depth for the 9 MeV energy has a small difference with the thickness of the bolus used. , where the depth for this 9 MeV energy is 2.1 cm. In theory, the thicker the bolus used, the lower the transmission factor value, if the transmission factor value is below 100%, the bolus can be said to be an absorbent material (Endarko et al, 2020).

3.4. Comparison of Absorbent Dose of Plasticine and Silicone Rubber Bolus

The absorbed dose was obtained by irradiating using the LINAC instrumentation at an energy of 9 MeV and 12 MeV, where the d_{max} values for each energy were 2.1 cm and 3 cm. The comparison of the absorbed doses of plasticine and silicone rubber boluses with thickness variations of 0.5 cm, 1 cm, 1.5 cm, and 2 cm can be seen in Figure 6.

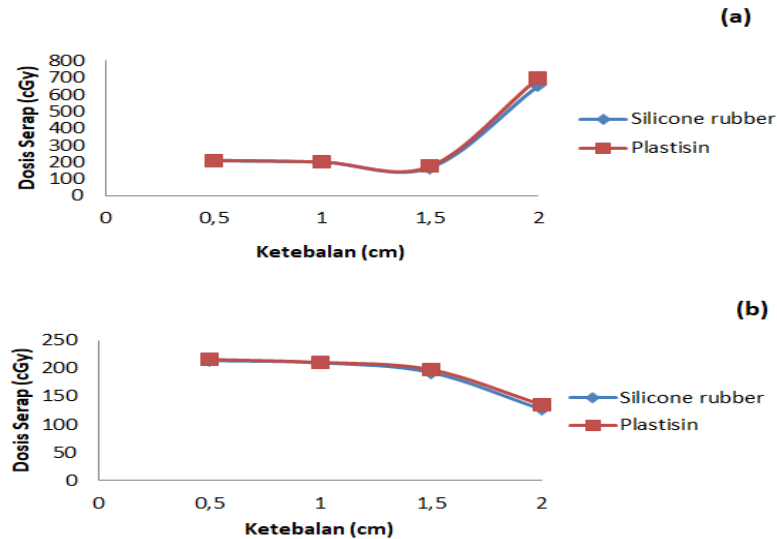


Figure 6. Comparison of absorbed doses of plasticine bolus and silicone rubber bolus (a) 12 MeV energy, (b) 9 MeV energy

From the results of the study, the value of the absorbed dose for each bolus irradiated with energy of 12 MeV shown in Figure 6 (b) obtained results according to the theory, but for the value of the absorbed dose for each bolus irradiated with energy of 9 MeV there is a discrepancy with the theory, where the value of the absorbed dose without a bolus of 208.5 cGy, while for a bolus of silicone rubber and plasticine at a thickness of 2 cm, the absorption dose value is higher than without a bolus of 654.7 cGy and 700.1 cGy, this happens because at a thickness of 2 cm there is a large difference. slightly with a maximum depth for energy of 9 MeV, thus causing an increase in the value of the absorbed dose. Theoretically, the thicker the bolus used, the shallower the range of absorption doses taken (Sianturi et al, 2019).

From the results of the study, it was found that silicone rubber boluses were more able to reduce the range of absorbed doses compared to plasticine boluses. In theory, boluses are used to even out the surface area, increase the dose on the surface and reduce the dose depth (Junaedi et al, 2016).

4. Conclusion

Based on the research that has been done, it can be concluded that from the synthetic process the bolus with silicone rubber material is easier to apply and the results of the bolus do not contain air bubbles, while the bolus with plasticine material still contains air bubbles. The RED value of the silicone rubber bolus and the plasticine bolus were both close to the density value of water, so both of these boluses could be said to be good boluses because the RED value was close to the water density value. Silicone rubber

boluses and plasticine boluses can be said to be absorbent, because the transmission factor value of the two boluses is below 100%. Based on the results of the absorption doses of the two boluses, it can be concluded that silicone rubber boluses can reduce the range of absorbed doses more than plasticine boluses, where theoretically the bolus is used to increase the surface dose and reduce the depth dose range, when viewed from the synthetic results of each bolus and dose. absorption obtained, the silicone rubber bolus is more effective to use.

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