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Characteristics of Bolus Using Silicone Rubber with Silica Composites for Electron Beam Radiotherapy

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ABSTRACT

Bolus is a material that equal with the tissue and functions to increase the dose radiation in surface area in external radiotherapy, which uses electron beam. In this research, bolus was made using silicone rubber (SR) material, which was mixed with silicacomposites material. The bolus with a dimension of $12 \times 12 \times 0,5 \text{ cm}^3$ was successfully made with a various amount of silica composite (2%, 4%, 6%). Bolus was then characterized using linear accelerator (LINAC) with an electron beam for percentage of surface dose (PSD) and using CT-Scan to measurement relative electron density (RED). The energy of electron beam used in this research was 5 and 7 MeV. The result shows that RED value increased with increasing the amount of silica composite with higher RED value amounted to 1.186. PSD value increased with increasing the amount of silica composite, higher PSD value of energy in 5 and 7 MeV amounted 106.82% and 106.82% and 100.34%, respectively. The result certified that the silica composite material can increase the percentage of surface dose on electron beam radiotherapy.

1. Introduction

Linear Accelerator (LINAC) is often used in external radiotherapy process for various cancer and is planned to produce multi energy in the form of photon beam and electron beam so that this instrument can be used to treat cancer in various position [1]. Radiotherapy is an action of radiation therapy treatment in a malignant tumor (cancer) by applying ionizing radiation, such as x-ray, gamma ray, or particle of electron with high energy [1,2]. The purpose of radiotherapy is to give precisely radiation dose to the cancer without giving damage effect to the health network surrounded [3,4]. For cancer case that placed in skin surface area, radiation beam usually uses electron beam [5]. Generally, the electron beam has a surface dose that does not reach 100%, so that to upgrade the surface dose to 100% it can be realized by using material that equals with tissue, which is known as bolus. The bolus usage in external radiotherapy has a various function such as (1) upgrade surface dose of patient, (2) compensation of un-flat surface patient body, and (3) reduce penetration of secondary electron beam at healthy tissue [6,7,8].

To make an equal material with tissue is not easy. Many researchers used a various material such as polymer gel, HARPC (highly absorbent polypropylene and rayon cloth), super flab, material thermoplastic, and silicone rubber (SR) [5,9,10].

However, those materials has many deficiencies such as polymer gel has low density compared with water, superflab has a deficiency in refraction which is less appropriate when being applied to the patient skin. Then, HARPC is only can be used in one-time usage. For thermoplastic material, eventhough it gives best result when being positioning on anathomy, it has deficiency when thermoplastic material is ran dry and ossified so that thermoplastic is hard to reposition to surface of a patient body [9-11]. SR material has various superiority such as it can be formed appropriately with the form of patient body, non-toxic, non-irritation of a skin surface and it had been proved can upgrade the dose of skin surface [5]. Compared with the others previous materials, SR material can be used as an alternative material to make bolus.

In this paper, bolus was made by using SR material, which is combined with silica composite material. The usage of silica as a composite in SR was many learned in various sectors such as electronic, and sealing product with the purpose to upgrade density and characteristic of SR mechanics [12-14]. However, it has not been yet applied for radiotherapy. The added of silica in SR as bolus material can increase the percentage of surface dose so the optimization in radiotherapy of a skin cancer use electron beam.

2. Material and Method

2.1. Bolus Fabrication

Bolus was produced using SR material that originates from silicone rubber RTV-52 with catalyst is bluesil catalyst 60 R as an amplifier of SR material and increment of silica as a composite. Silica was gained from synthesis result of geothermal power plant waste (Physics, Material Laboratory, Diponegoro University) with the purity amounted of 70%. In Bolus preparation, bolus was molded using wood molding with the dimension of 12 x 12 x 0.5 cm³. Bolus was produced with the composition of SR and catalyst at amount of 72 ml and 2.9 ml, respectively. The increment of silica composite has amount of 2%, 4%, and 6%, the sample was labeled with name tag of A, B, C, and D, where Sample A is a sample with SR material without silica composite, sample B, C and D are sampled with increment of silica composite with each compliment is 2%, 4%, and 6%, respectively.

SR and silica composite material were mixed in two-time mixing process. The first mixing process was SR and silica composite materials was mixed by using mixer at around 15 minutes. The sample was then cleaned using ultrasonic at around 30 minutes with a temperature of 40 °C. After cleaning process, second mixing process was made using mixer at around 6 minutes by adding a catalyst. The mixing result was poured to the mold and waited until the material is completely hard and ready to lift from the molding.

2.2. Relative Electron Density (RED) Measurement

Data relative electron density (RED) was gained from the CT-Number value that automatically gained after obtained topography image in axial scanning used CT-Scan (General Electric, USA). In taking CT-Number value was conducted as many as 10 spots of interpretation data by made region of interest (ROI) area in the form of a circle and between the taking samples are 1 cm. After the gained CT-Number value of each sample, to find RED value used equation as follows:

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

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

with ρ_a is RED value with CT-Number value more than 100, ρ_b is RED value with CT-Number value less than 100, and N_{CT} is CT-Number value [15]. RED value of each network can be seen in Table 1.

Table 1. Value of relative electron density (RED) of many tissue

Tissue	RED	Reference
Muscle	1.043	[16]
Liver	1.052	[16]
Breast	0.976	[17]
Dense bone	1.512	[17]

2.3. Percentage of Surface Dose (PSD) Measurement

In this research, Percentage of Surface Dose (PSD) Measurement was conducted in Radiotherapy Installation, Ken Saras Hospital, Bergas, Indonesia. PSD value was gained by giving radiation of electron beam at solid phantom without using bolus and used bolus. Electron beam energy was from a linear accelerator (LINAC) (Siemens Primus, Germany) amounted 5 and 7 MeV, respectively. Applicator field used wide field 10 x 10 cm² and source to surface distance (SSD) arranged in a position of 100cm from the solid phantom surface.

The procedure of interpretation data was conducted by put the detector of plan parallel chamber (IbaDosimetry, Sweden) above the surface and depth position of maximum dose (Z_{max}) at the solid phantom. Value of Z_{max} for 5 and 7 MeV energy is amounted 1.1 cm and 1.5 cm, respectively. Data interpretation process can be seen in Fig. 1. The measurement result is content data that appeared at electrometer (IbaDosimetry, Sweden) innanocoloumb (nC) order. To measure the percentage of surface dose in the solid phantom surface, a following equation was employed:

$$PSD = Q_s / Q_{Z_{max}} \times 100\%$$

With Q_s is contents value that measured in surface position of solid phantom and $Q_{Z_{max}}$ is contents value that measured in position of Z_{max} [5].

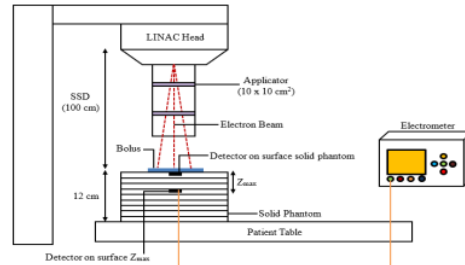


Fig 1. Scheme of percentage of surface dose (PSD) measurement

3. Result and Discussion

3.1. Bolus Synthesis Results

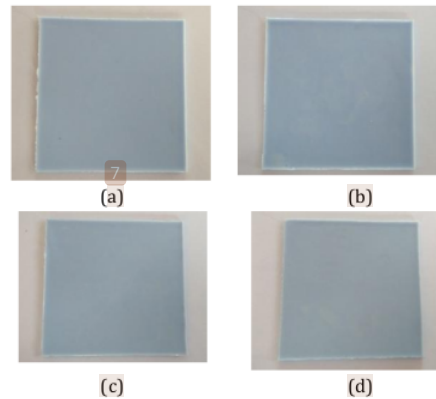


Fig 2. Bolus synthesis result (a) A sample without silica, (b) B sample with silica 2%, (c) C sample with silica 4%,

and (d) D sample with silica 6%

In this research, bolus is successfully made and can be seen in Fig. 2. Each sample has a flat surface and there is no air bubble on the surface. It is because in the process of bolus printing can be minimized because the distance between molding and pouring process is near at around 10 mm. This is also due to the assessment process during the synthesis process in the form of a cleaning process by ultrasonic.

3.2. Bolus Tomographic Image

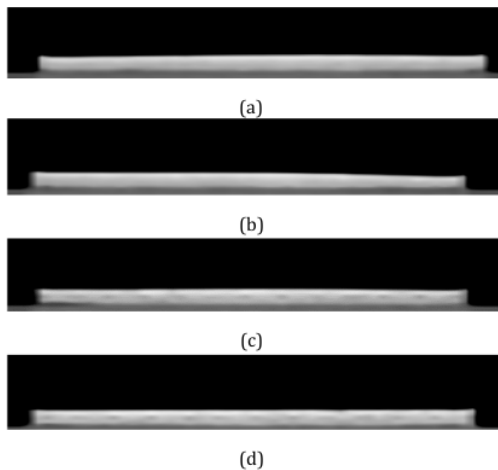


Fig 3. Bolus tomographic images in axial scanning (a) A sample without silica, (b) B sample with silica 2%, (c) C sample with silica 4%, and (d) D sample with silica 6%

The axial tomographic image which obtained from CT-Scan can be seen in Fig. 3. It can be seen that each sample is homogenous and there is no air bubble. This matter shows that all samples have the main requirements of a bolus that is no air bubbles on each surface [17]. From the CT-Scan data, the HU value was also obtained, which is used to calculate the relative value of the density electron. CT-scan images show relatively similar tomography but actually have different HU values, namely for sample A, B, C, D are 240, 251, 255, 281, respectively.

3.3. Relative Electron Density (RED)

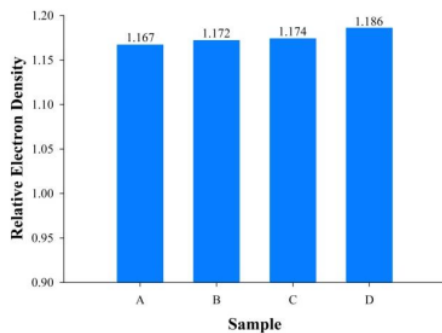


Fig4. Relative electron density (RED) graphs of each sample

The value of HU obtained for each sample is above 100 so that the RED value is calculated using Eq. (1). Relative electron density (RED) value for each sample can be seen at Fig. 4. Based on Fig. 4, sample A has RED value amounted to 1.167 while for sample B, C, and D has RED value amounted to 1.172, 1.174, and 1.186, respectively. Research result shows that much more silica composite material that used, much more increase the RED values was. This research result is appropriate with the result reported by Tarakoshi et al that used increment concentration of K_2HPO_4 solution to measure the electron density value with dual-energy x-ray used synchrotron radiation [18]. If compared with the RED value in Table 1, RED value for all samples is above the soft tissue such as muscle, liver, and breast, while if sample compared with solid tissue such as dense bone, RED value of sample is lower. This is because of the atom contradiction of arranging each tissue so that give different solid value to each tissue. But in entirety, the RED value of each sample is in distance of RED value tissue.

3.4. Percentage of Surface Dose (PSD)

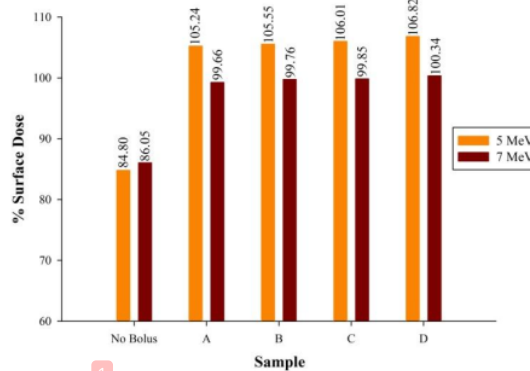


Fig 5. Percentage of surface dose (PSD) on the solid phantom surface for each sample

The value of percentage of surface dose (PSD) for each sample can be seen in Fig. 5. Based on Fig. 5, PSD value without using bolus in an energy of 5 and 7 MeV are 84.80% and 86.05%, respectively. The value of PSD increased to above 100% when using a bolus of the synthesis results. From this research, the results show that much more silica composite used, the higher PSD value was so that the PSD value that produced is higher. The result can be seen in sample D, which has higher PSD value at amount of 106.82% and 100.34% for the energy of 5 and 7 MeV, respectively. It is because of the big of density material so it had lower stopping power value if compared with the more solid material [19]. Finally, electron particle will lose kinetic energy and make dose at the surface area of solid phantom is more increased [20].

Conclusion

In this research, bolus was successfully made using SR material by varying the concentration of silica composite. RED value of each sample is above the soft network with higher RED value at amount of 1.186. PSD value that produced by each samples was above 100% with higher PSD value for the energy of 5 and 7 MeV at amount of 106.82% and 100.34%, respectively. The increment of silica composite in SR material can increase the RED and PSD values. Therefore, it gives optimization on radiotherapy process with an electron beam.

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