Utilization of Alginate Powder Strengthened with Silicon Rubber as Composite Bolus Material for Radiotherapy 8 Mev Energy

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Abstract: Cancer is one of the highest causes of death in the world. The incidence is increasing every year. the incidence of cancer in Indonesia (136.2 / 100,000 population) ranks 8th in Southeast Asia, whereas in Asia ranks 23rd. Radiotherapy is a cancer treatment method that utilizes ionizing radiation. Research is conducted on the use of alginate powder which is reinforced with silicon rubber as a composite bolus material for radiotherapy shield applications at 8 mev energy. bolus composite as a radiotherapy shield using a mixture of silicon rubber, catalyst and alginate powder in variations (80:18:2)% wt, (80:16:4)% wt, (80:14:6)% wt, (80:12:8)% wt and (80:10:10)% wt also with bolus thicknesses of 5 mm, 10 mm and 15 mm. A mixture of silicon rubber is one of the synthetic polymer materials derived from polydimethylsiloxane (PDMS), alginate powder and catalysts are expected to fill the blanks of bolus made from PDMS so that it has a more even density. Composite boluses were analyzed using CT-Scan to determine the relative electron density (RED) value, mechanical properties (tensile strength, and elastic modulus), and absorbed dose analysis using electrons at 8 MeV energy.

1 INTRODUCTION

Cancer is one of the highest causes of death in the world. the incidence is increasing every year. According to WHO, cancer is a general term for a large group of diseases that can affect every part of the body. Other terms used are malignant tumors and metastatic neoplasms which are the main causes of cancer deaths. Based on Globocan data, in 2018 there were 18.1 million new cases with a mortality rate of 9.6 million deaths from cancer, where one in five men and one in six women in the world experience cancer. The data also states that one in eight men and one in 11 women died of cancer. Director General of Disease Prevention and Control (P2P) Ministry of Health (Kemenkes) Anung Sugihantono explained the incidence of cancer in Indonesia (136.2 / 100,000 population) ranks 8th in Southeast Asia, whereas in Asia 23rd. Seeing a high enough number, the Ministry of Health is undertaking prevention efforts that go hand in hand with prevention for cancer sufferers in Indonesia, namely by optimizing health facilities, early detection for those who have not been detected by cancer, and radiotherapy to those affected by cancer as a step to control cancer. Radiotherapy is a cancer treatment method that utilizes ionizing radiation. Linear accelerator (Linac) is a radiotherapy device that consists of a number of discrete components. Linac serves to accelerate high-energy electrons by using RF waves before the electrons reach the target to produce X-rays. Nowadays linear accelerators can produce two different energies namely X-rays and electrons (Chianese and Chamberlain, 2009)

However, during the process of radiotherapy using linac, it was found several other problems that there were some radiation beams which were likely to affect healthy tissue (normal) so that it could potentially cause unwanted new cancers. Then, when treating cancer that is on the surface of the skin (Superficial), the surface dose resulting from the use of electron beams has not reached 100%. So as to overcome these problems a radiotherapy facility known as a bolus is needed.

Bolus in radiotherapy at this time which has advantages and disadvantages, but in general to use boluses, the main thing to note is the flexibility of the material must be checked, the material must be stable with temperatures between 4°C to 52°C and dosimetric properties and electron density must be equivalent to water. In addition, the bolus to be used is odorless, non-sticky, and not harmful to the skin

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(Podgosark, 2006). Based on research from Dodi Junaedi in the manufacture of commercial boluses from PDMS material, with the title of the analysis of the use of polydimethyl siloxane as a bolus in radiotherapy to assess the feasibility of using polydimethyl siloxane as a material for making radiotherapy boluses with thickness variations to determine the value of CT Number and absorption dose with 8 MeV electrons from the results of the study found that the nature of polydimethyl siloxane can increase the surface dose, decrease the dose range depth and density similar to soft tissue (Junaedi, 2016). Composite is an amalgamation of different materials whose purpose is to find new materials that have intermediate properties of the constituent materials which would not be obtained if the constituent materials stand alone. The nature resulting from the incorporation of materials is expected to improve the weaknesses and weaknesses of the constituent materials (Rianto, 2011).

Composite material consists of two main constituents namely matrix and reinforcement / reinforcement. The matrix is a component forming and binding in the composite. Some composites have a combined matrix consisting of two or more layers with different compositions and arranged alternately while the filler as a reinforcing material or filler on the composite (Nayiroh, 2013).

Utilization of silicon rubber in polymer resin as a matrix phase is an engineering that is carried out to obtain the elastic characteristics of composite materials. Considering that silicon rubber is part of a polymer that has advantages in terms of elasticity, so mixing the two is identified as being able to provide better toughness properties (Sujana and Widi, 2014). Alginate is part of a linear copolymer consisting of two monomeric units, namely D-mannuronic acid and L-guluronic acid. One of the most important properties in the use of sodium alginate, potassium alginate and magnesium alginate is its ability to form gels that are adapted to calcium ions. Sources of calcium are usually in the form of calcium carbonate, calcium sulphate, calcium chloride, calcium phosphate and calcium tartrate. Besides having the ability to form a gel, alginate is also used as a thickener (water binder), emulsifier, and stabilizer (Kirk, 1994).

Relative electron density (RED) is used as a tool to capture images and to test the performance of bolus radiotherapy by first determining the bolus tomographic image capture using CT-Scan. 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 image on the bolus are sent to the computer so that the CT-Number value can be read in the treatment planning system (TPS) program. The relative electron density (RED) value of bolus silicone rubber without alginate mixture is 1.168 (Mayles et al., 2007).

Based on the description above, a study was carried out on the use of alginate powder reinforced with silicon rubber as a composite bolus material for radiotherapy shielding applications at 8 MeV energy. Composite bolus as a radiotherapy shield by using a mixture of silicon rubber, catalyst and alginate powder at variations (80:18:2)% wt, (80:16:4)% wt, (80:14:6)% wt, (80:12:8)% wt and (80:10:10)% wt also with bolus thicknesses of 5 mm, 10 mm and 15 mm. A mixture of silicon rubber is one of the synthetic polymer materials derived from polydimethylsiloxane (PDMS), alginate powder and catalysts are expected to fill the blanks of PDMS-based bolus so that it has a more even density. Composite boluses were analyzed using CT-Scan to determine the relative electron density (RED) value, mechanical properties (tensile strength, and elastic modulus), and absorbed dose analysis using electrons at 8 MeV energy.

2 METHODOLOGY

The method used in making bolus material in this study is the coprecipitation method, which uses a chemical solution deposition technique that is mixed with the wet mixing method which is then molded and cooled.

2.1 Tools and Materials

Digital Balance, 100 mL Plastic Beaker, Bowl, Mixer, Glass, Spatula, Oven, Caliper, Scissor, Linear Accelerator (LINAC) brands from Siemens Primus, Solid Water Phantom, Computed Tomography Scanner (CT-Scanner) Chamber Plan Parallel Ultimate Testing Machine, Alginate as filler material for RTV 52 Silicone rubber as a matrix (adhesive), bluesil Catalist 60R.

2.2 Research Procedure

The stages of the use of alginate powder reinforced with silicon rubber as composite bolus material for radiotherapy shielding applications at 8 mev energy, namely making bolus using materials: alginate powder, silicone rubber, bluesil catalyst, testing mechanical properties (tensile strength, and elastic modulus), CT-Scan to determine the relative electron density (RED) value, and absorbency dose analysis using electrons at 8 MeV energy.

3 RESULTS AND DISCUSSION

Based on the research that has been done, namely the use of alginate powder reinforced with silicon rubber as a composite bolus material for radiotherapy shielding applications at 8 MeV energy, the results of the tests performed are mechanical tests (tensile strength and elastic modulus), analyzed using CT-Scan to determine the relative electron density (RED) value, and absorbance dose analysis using electrons at 8 MeV energy.

3.1 Tensile Strength Test

Tensile strength is a test performed to determine the ability of radiotherapy bolus in holding a load or a vertical mechanical force that is given until the occurrence of broken or broken where tensile strength testing using Universal Testing Machine (UTM) with ASTM D 882. From the results of research conducted using the Strong equation Pull = F / A

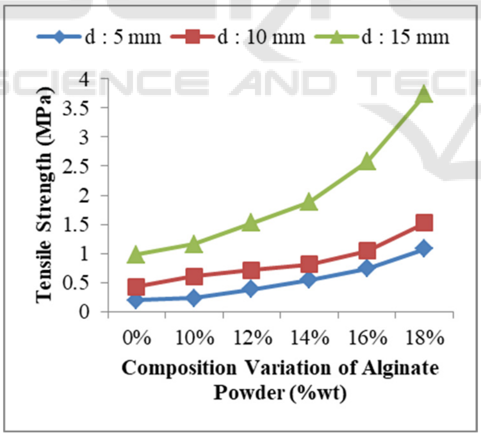

Figure 3.1. Results of Bolus Tensile Strength Test Based on Alginate Powder and Silicon Rubber in Various Composition Variations

From observations based on the graph in Figure 3.1. above shows that the value of tensile strength increases in proportion to the increase in the composition of the filler (filler), namely alginate powder. This is shown from the results of the study that the optimum conditions obtained tensile strength values in the composition of silicone rubber: alginate powder (80:20) % wt at a thickness of 15 mm is 3.834 MPa and less optimum conditions in the composition of silicone rubber: alginate powder (80:12)% wt at a thickness of 5 mm produces a tensile strength of 0.329 MPa. The value of tensile strength decreases when the filler mass of alginate powder decreases causing hydrogen (H_2) bonds and makes the distance between the bolus polymer chains more tenuous. Where the hydrogen bond is a very weak bond, weaker than the covalent bond which causes an increase in the speed of viscoelastic response and molecular mobility of polymer chains in the compiler of radiotherapy bolus.

3.2 Modulus of Elasticity

Elastic modulus test is a test that aims to find out how resistant a bolus material experiences strain to elastic deformation when given vertical outside stress. Where the elastic modulus testing procedure refers to ASTM D 882-97 which results in the following graphic form:

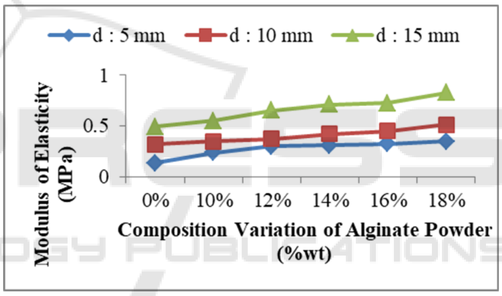

Figure 3.2. Test Results for Young Bolus Modulus Based on Alginate Powder and Silicon Rubber in Various Composition Variations

Figure 3.2. shows that the modulus of elasticity increases in proportion to the addition of alginate powder composition and bolus thickness. The results showed that the bolus which had optimum modulus of elasticity in the composition of silicone rubber: alginate powder (80:20)% wt at a thickness of 15 mm was 0.8252 MPa. Whereas the variation condition which has less optimum modulus of elasticity in the composition of silicone rubber: alginate powder (80:12)% wt with a thickness of 5 mm is 0.1321 MPa. Modulus of elasticity is affected by the addition of alginate powder and thickness which triggers the viscoelastic response and mobility of the siloxan chain molecule (Si-O-Si) formed from silanol (Si-OH) silicon rubber groups causing the elasticity of the radius bolus to increase and the stiffness of the bolus material to decrease. Silicon rubber as a matrix has properties that can increase the flexibility, elongation

and strength of the polymer so that it reduces the hardness and stiffness of the polymer because it increases the distance between chains by reducing bonds between secondary molecules.

3.3 Relative Electron Density (RED)

Bolus radiotherapy based on alginate powder composite reinforced by silicone rubber scanning process using CT-Scan to obtain bolus tomographic images in axial and coronal directions with the aim to take the CT-Number value. CT-Number that has been obtained depends on the value of CT-Number obtained. The relative electron density (RED) value of pure silicon rubber bolus without mixture is 1.168. When compared with the RED value of pure silicone rubber bolus composite with composite bolus of alginate powder reinforced with silicone rubber.

Where the value of RED bolus has an important role when the dose distribution calculation process is performed when the patient uses bolus, so it can be known how much the estimated radiation dose received by the patient on the skin surface area and under the skin surface. To reassure the results of the compatibility of composite boluses with tissue types, a calculation based on the composition of the optimum alginate powder and bolus thickness and various tissues using the effective atomic number (EAN) calculation produces the following graphical form:

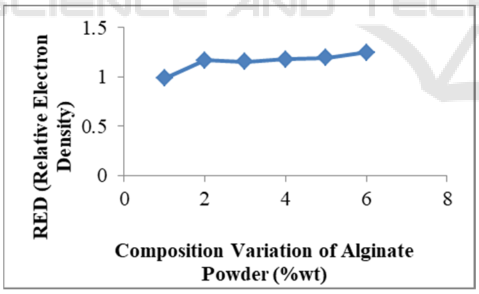

Figure 3.3 Test Results of RED Bolus Radiotherapy Based on Composite Alginate / Silicon Rubber with CT Scans on Various Composition

Figure 3.3 shows that the optimum conditions obtained relative electron density (RED) value from the CT scan results on the composition of silicone rubber: alginate powder (80:20)% wt of 1.251 with CT Number 241.4 HU, while for bad conditions on the composition of silicon rubber: alginate powder (80:12)% wt with RED 1.152 with CT Number 414.9 HU. The increase in the RED value is influenced by the composition of the alginate powder, which is the bond of inorganic polymers of silicon rubber in the form of siloxane bonds consisting of silicon (Si) and oxygen (O) atoms and methyl bonds consisting of carbon (C) and hydrogen atoms are optimum for bind the filler alginate powder so that it is denser and stronger. Where the bolus material density affects the absorption of material to the x-rays received by the bolus.

3.4 Percentage of Dose Absorption on the Surface

Bolus shielding radiotherapy based on alginate powder composite reinforced by silicone rubber each tested using LINAC to find out how much percentage of the surface dose produced in electron beams with 8 MeV energy calculated by the equation D = (dε) / dm. With the same calculation, it can be made a measurement chart for the absorption dose value on the surface of the silicone rubber-based bolus material and alginate powder as follows:

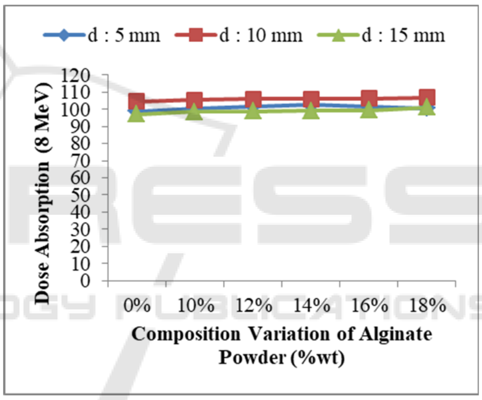

Figure 3.4 Test Results Percentage of 8 MeV Absorbed Doses in Alginate / Silicon Rubber Composite-Based Boluses in Various Composition Variations

From the observations above, the graph shows that the absorbance dose increases in proportion to the increase in the composition of the alginate powder and the thickness of the radiotherapy bolus. This is shown from the results of the study that the optimum conditions obtained absorbance values at 8 MeV are good on the composition of silicone rubber: alginate powder (80:20)% wt at 10 mm thickness of 106.92% which the absorbent dose without bolus is 93%. This increase in absorbency dose occurs due to differences in scattering (scattering) that occurs when electron particles pass through the medium (solid phantom). For low-energy electron beams, electrons become more easily scattered when interacting with a medium (solid phantom), consequently the electron beam fluence becomes more increased because of the greater scattering angle (ɵ).

This results in the area of build-up that occurs not too deep after passing through the surface of a solid phantom, so that the ratio of the surface dose to the maximum dose becomes smaller in the use of electrons with low energy. But overall the increase in the percentage of surface doses in solid phantom has not reached 100%. To increase the percentage value of the surface dose, a bolus with a uniform thickness of 5 mm to 15 mm is used.

4 CONCLUSION

Research on the Utilization of Alginate Powder Strengthened by Silicon Rubber as a Composite Bolus Material for Radiotherapy Shielding Applications at 8 Mev Energy, using a chemical solution deposition method. In research with composite bolus material made from alginate powder reinforced with silicon rubber the following results were obtained: the optimum composition is a variation of the composition of silicone rubber: alginate powder: catalyst (80:18:2)% wt at a thickness of 15 mm has strong mechanical properties pull of 3.734 MPa, and modulus of elasticity of 0.8252 MPa. optimum composition variation, namely silicone rubber: alginate powder (80:18)% wt at 15 mm thickness has CT number density properties that meet tissue standards in phantom testing for therapeutic media with a value of relative electron density (RED) from the CT Scan results on the composition of 1.251 produced a surface absorbency dose for 8 MeV of 106.92%.

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