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Equivalence Analysis of Radiotherapy Boluses Made from Polymer Clay with a Mixture of Aluminum Oxide Metal Powder Based on CT Number and Relative Electron Density

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Abstrak. Bolus is a radiotherapy tool that is often used for cases of tumors or cancer that are located on the surface of the skin. The aim of this research was to determine the equivalence of polymer clay with tissue as a bolus material in radiotherapy treatment. By using the image capture method on a CT scan using axial scanning with voltage and current according to the clinical examination, the bolus image results can be viewed on a computer so that they can be read according to the CT Number using RadiAnt DICOM Viewer software. The effect of $Al2O3$ metal powder on polymer clay can be seen from the CT Number and Relative Electron Density graphs produced. From the CT Number (HU) results of polymer clay with a mixture of metal powder $Al2O3$ 0g, 1g, 4g, 7g, 8g, and 10g, the parameters of the head, thorax, abdomen are close to lung tissue, skin tissue, soft tissue, and fat tissue. Meanwhile, the results of the Relative Electron Density (RED) values for polymer clay with a mixture of metal powder $Al2O3$ 0g, 1g, 4g on the head, thorax and abdominal parameters are close to lung tissue. However, the value of RED polymer clay with a mixture of metal powder $Al2O3$ 4g on the thorax parameters and the value of RED polymer clay with a mixture of metal powder $Al2O3$ 7g, 8g and 10g on the parameters of the head, thorax and abdomen are not close to the tissue.

Keywords: Polymer clay, Bolus, Radioterapi, CT Scan, CT Number, Relative Electron Density

I. Introduction

Radiotherapy is an alternative method used in the process of curing cancer by utilizing ionizing radiation as a source of radiation therapy. Ionizing radiation consists of electromagnetic radiation and particle radiation. This radiotherapy aims to destroy cancer tissue and can be used to treat almost all cancers such as skin cancer, breast cancer and prostate cancer [1]. However, there are some healthy tissues or organs that are at risk (OARs). There has been much effort in characterizing the anatomical changes in human organs at risk of Organs at risk (OARs) and the dosimetric consequences during radiotherapy treatment [2].

Organs at risk (OARs) are healthy tissues or organs placed close to the clinical target volume (CTV) whose radiation can cause tissue damage during radiotherapy treatment. In particular, radiotherapy can cause early (acute) and delayed (slow) damage to organs at risk (OARs), therefore from the beginning the application of radiotherapy is carried out by reducing toxicity due to radiation that has developed in the tissue.

Radiotherapy used to kill cancer cells can also cause side effects on healthy tissue around the targets (OARs). Excessive doses in surrounding healthy tissue may increase the risk of secondary cancer. To be able to determine the dose received by the surrounding tissues (OARs) in cancer cases by adding a bolus around the skin [2].

Bolus is a radiotherapy tool used for cases of tumors or cancer that are located on the surface of the skin with the aim of providing an increased dose to the surface area of the skin [1]. Several researchers have used bolus materials that are equivalent to human tissue, such as wax, silicone rubber and water hyacinth. When making boluses, materials must be used that are compatible with the tissue so that the bolus can stop particle movement and scattering [3]. To use a new material as a bolus properties such as plasticity and tensility must be checked. In addition, the bolus substance must be stable at all temperatures and have the same dosimeter properties as water, the bolus substance must be odorless, non-sticky and harmless to the skin.

In this study, researchers used polymer clay as a bolus material because the material is cheap, easy to obtain and does not require a long time so it can be used in radiotherapy treatment. This polymer clay has a soft texture so it can be used as a bolus material for radiotherapy treatment. Polymer clay also has a mass density close to that of water, making it suitable for development as a bolus material [4]. The composition of polymer clay is water, plastics, synthetic materials, and pigments. The aluminum used in this research is aluminum oxide (Al_2O_3) with 500 Mesh because aluminum powder has a fairly economical price. Metal powder Al_2O_3 is a metal that is thermodynamically a metal that is reactive or easy to act. Apart from that, aluminum is also non-toxic so it is safe to use as a mixture for polymer clay.

From making the synthetic bolus, a CT Scan process is carried out to obtain a bolus tomography image in the axial and coronal areas with the aim of taking the CT Number [5]. CT Scan is a radiodiagnostic examination tool that uses a computer to carry out reconstruction obtained from a number of rows of detectors to receive X-ray beams.

The basic principle of a diagnostic CT scan is to use the principle of attenuation of X-ray energy (attenuation) on the object being illuminated. In CT scanners, the process occurs when the computer completes image reconstruction. The results of this image reconstruction are converted to a CT Number scale.

II. Method

From the results of making a synthetic bolus, a CT Scan process is carried out to obtain a bolus tomography image in the axial and coronal areas with the aim of taking the CT Number [4]. CT Number is the value of the X-ray attenuation coefficient of a tissue that is observed and compared with water attenuation in HU (Hounsfield Unit) units and then displayed on the computer screen in grayish color [7]. CT Number can also be expressed with the formula:

$$CT\ Number = K\frac{\mu_j - \mu_\alpha}{\mu_\alpha} \quad (1)$$

Organ density is expressed in Relative Electron Density (RED), so the relationship between CT Number and Relative Electron Density (RED) needs to be measured and then transferred to the RadiAnt DICOM Viewer, so that the CT Number value for each different tissue must not differ significantly from the value used in the RadiAnt DICOM Viewer. If there is a discrepancy between the CT Number value for a particular type of tissue and the CT Number value at the TPS, there will be an error in the accuracy of the treatment plan obtained.

The RED value can be calculated using the equation for CT numbers greater or less than 100 [7].

$$\rho_\alpha = 1{,}052 + 0{,}00048\ N_{CT},\ N_{CT} > 100 \quad (2)$$

$$\rho_\beta = 1{,}052 + 0{,}001\ N_{CT},\ N_{CT} < 100 \quad (3)$$

When taking the CT Number on the bolus by determining the region of interest (ROI) in a circle as many as 5 areas. The Roi area can be adjusted to the size of the small circle in the RadiAnt DICOM Viewer program. From the results of the CT Number values obtained, RED values can be generated using equations 2 and 3.

Researchers analyzed by making graphs the variations in metal powder mixtures Al_2O_3 used for the resulting CT Number (HU) and Relative Electron Density (RED) values so that they can be analyzed properly. After getting the results of the equality of CT Number (HU) and Relative Electron Density (RED) of polymer clay with normal tissue, the researchers analyzed it by looking at the equality results of several previous research results.

III. Result and Discussion

The CT Number (HU) and Relative Electron Density (RED) values have an important role in calculating the dose distribution when the patient uses a bolus, so that it can be known how much radiation dose the patient receives in the skin surface area and below the skin surface to ensure a suitable bolus. certain types of networks. Results from data processing of polymer clay with a thickness of 1 cm each and mixed variations Al_2O_3 0g, 1g, 4g, 7g, 8g, and 10g using the parameters of the head, thorax, abdomen, they are read according to the CT Number value in the RadiAnt DICOM Viewer program and the Relative Electron Density value is obtained using equations 2 and 3.

Table 1. CT Number Hounsfield Unit (HU) and Relative Electron Density (RED) values in boluses with various metal powder mixtures Al_2O_3 with CT simulator head parameters at a voltage of 120 kV and 199 mA.

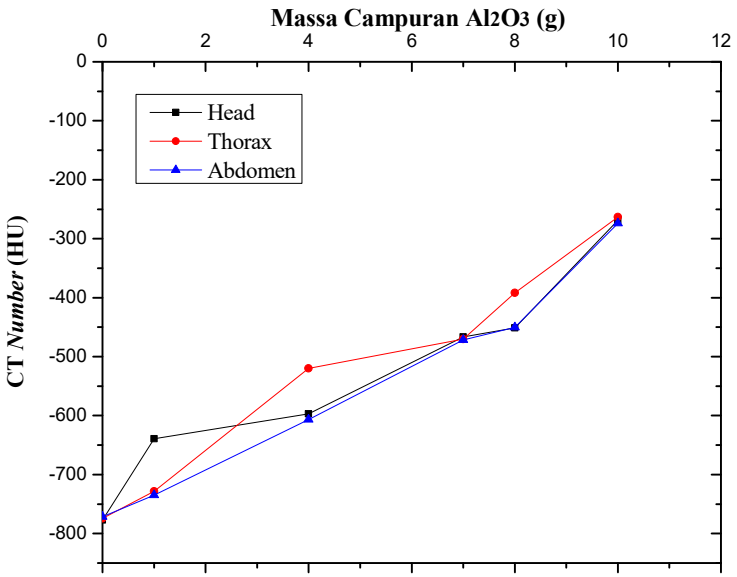
Type Parameter	Mixed Variations Al_2O_3	CT Number Hounsfield Unit (HU)	Relative Electron Density (RED)
Parameter *Head*	0 g	-777,243 ± 1,326787	**0,274757**
	1 g	-639,142 ± 1,581873	**0,412858**
	4 g	-596,976 ± 1,59344	**0,455024**
	7 g	-466,585 ± 1,54388	**0,585415**
	8 g	-451,201 ± 1,76613	**0,600799**
	10 g	-268,865 ± 1,63472	**0,783135**

Table 2. CT Number Hounsfield Unit (HU) and Relative Electron Density (RED) values in boluses with various metal powder mixtures Al_2O_3 with CT simulator head parameters at a voltage of 120 kV and 98 mA.

Type Parameter	Mixed Variations Al_2O_3	CT Number Hounsfield Unit (HU)	Relative Electron Density (RED)
Parameter *Thorax*	0 g	-774,155 ± 2,125733	**0,277845**
	1 g	-728,41 ± 1,392167	**0,32359**
	4 g	-520,12 ± 2,699727	**0,53188**
	7 g	-470,475 ± 2,111893	**0,581525**
	8 g	-391,828 ± 2,655013	**0,660172**
	10 g	-263,446 ± 3,065747	**0,788554**

Table 3. CT Number Hounsfield Unit (HU) and Relative Electron Density (RED) values in boluses with various metal powder mixtures Al_2O_3 with CT simulator head parameters at a voltage of 120 kV and 147 mA.

Type Parameter	Mixed Variations Al_2O_3	CT Number Hounsfield Unit (HU)	Relative Electron Density (RED)
Parameter *Abdomen*	0 g	-771,627 ± 1,80238	**0,280373**
	1 g	-734,863 ± 1,928327	**0,317137**
	4 g	-606,614 ± 2,226627	**0,445386**
	7 g	-471,682 ± 2,41736	**0,580318**
	8 g	-450,483 ± 2,732714	**0,601517**
	10 g	-273,835 ± 2,770967	**0,778165**

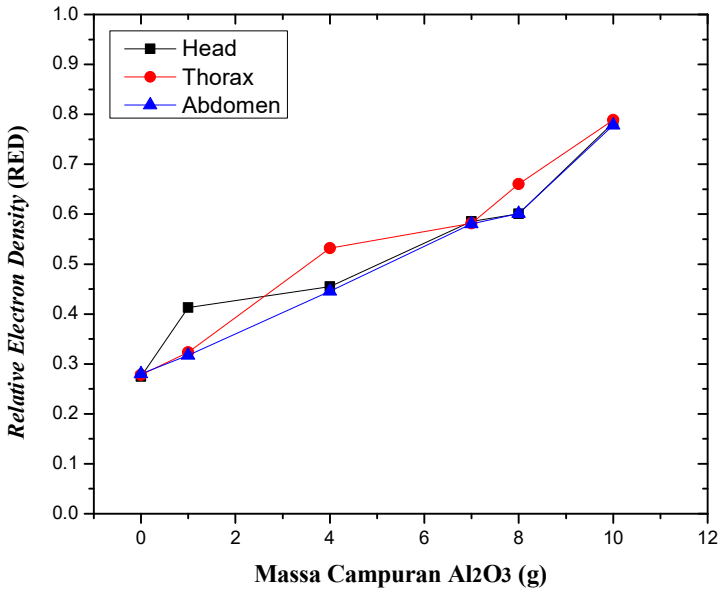


Picture 1. Graph of CT Number (HU) of bolus with metal powder mixture Al_2O_3 on head, thorax and abdomen parameters.

If you look at Figure 1, the results show the CT Number value for polymer clay with a mixture of 0 g Al_2O_3 has a CT Number value of -777,243 in the head parameter which is close to the lung tissue (Inhale) with a CT Number value of -778[8]. Polymer clay with a mixture variation of 0 g has a CT Number value of -774.155 on thorax parameters, and a CT Number value of -771.627 on abdominal parameters and polymer clay with a mixture variation of 1 g metal powder Al_2O_3 has a CT Number value of -639.142 in the head parameter, a CT Number value of -728.41 in the thorax parameter, and a CT Number value of -734.863 in the abdominal parameter which is close to the lung tissue (Inhale) with a CT Number value of -778 to -679[8] and approaches skin tissue with a CT number value from -766 to -718 and soft tissue has a CT number value of -700 [9]. Meanwhile, polymer clay is mixed with 4g metal powder Al_2O_3 has a CT Number value of -596.976 in the head parameter, a CT Number value of -520.12 in the thorax parameter, and a CT Number value of -606.614 in the abdominal parameter, approaching lung tissue with a CT Number value of -500[6].

In polymer clay with a mixture of 7 g of metal powder Al_2O_3 has a CT Number value of -466,585 in the head parameter, a CT Number value of -470,475 in the thorax parameter, and a CT Number value of -471,682 in the abdominal parameter. Polymer clay with a mixture of 8g metal powder Al_2O_3 has a CT Number value of -451.201 in the head parameter, and a CT Number value of -450.483 in the abdominal parameter which is close to the lung tissue (Exhale) which has a CT Number value of -488.95[6]. In polymer clay, there are variations of a mixture of 7 g of metal powder Al_2O_3 has a CT Number value of -391.828 on thorax parameters, and Polymer clay with a mixture of 10 g of metal powder Al_2O_3 has a CT Number value of -268,865 on the head parameter, a CT Number value of -263,446 on the thorax parameter, and a CT Number value of -273,835 on the abdominal parameter which is close to soft tissue with a CT Number value of -300 to -100[11], fat tissue with a value CT Number -205 to -212[12] and lung with a CT Number value of -200[13].

Based on the results of the CT Number (HU) value in Figure 1, polymer clay uses a mixture of metal powder Al_2O_3 with variations of 0g, 1g, 4g, 7g, 8g, 10g, and with variations in head, thorax, and abdominal parameters. Where is the CT Number value of polymer clay with metal powder Al_2O_3 0g with head parameters approaching lung tissue (Inhale), at the CT Number value of polymer clay with metal powder Al_2O_3 0g with thorax, abdominal parameters and CT Number values of polymer clay with a mixture of metal powder Al_2O_3 1g in the parameters of the head, thorax, abdomen, it is close to skin tissue. For the CT Number value of polymer clay with a mixture of metal powder Al_2O_3 4g in terms of head, thorax and abdominal parameters, it is close to lung tissue. Meanwhile, the CT Number value is polymer clay with a mixture of metal powder Al_2O_3 7g on the parameters of the head, thorax, abdomen and CT Number value of polymer clay with a mixture of metal powder Al_2O_3 8g in head parameters, the abdomen approaches the lung tissue (Exhale). At the CT Number value with a mixture of metal powder Al_2O_3 7g pthere are thorax parameters and the CT Number value of polymer clay with a mixture of metal powder Al_2O_3 10g in the parameters of the head, thorax, abdomen, it is close to soft tissue, fat tissue and lung.



Picture 2. ***Relative Electron Density (RED) graph of bolus with metal powder mixture*** Al_2O_3 **on head, thorax and abdomen parameters.**

Figure 2 shows that the bolus density value of polymer clay increases due to variations in the metal powder mixture Al_2O_3 yang added. Based on Figure 2, it shows that the results of the Relative Electron Density (RED) value on polymer clay with a variation of 0 g have a RED value of 0.274757 on the head parameter, have a RED value of 0.277845 on the thorax parameter and have a RED value of 0.280373 on the abdominal parameter. which approaches lung tissue (Inhale) with RED values of 0.20 [9] and 0.190 [14]. Meanwhile, polymer clay varies with 1 g of metal powder mixture Al_2O_3 has a RED value of 0.412858 in the head parameter, polymer clay with a variation of 4g mixed with metal powder Al_2O_3 has a RED value of 0.455024 in the head parameter, and has a RED value of 0.445386 in the abdominal parameter which is close to the lung tissue (Exhale) with a RED value of 0.496 [15]. In polymer clay with variations of 1g mixed with metal powder Al_2O_3 has a RED of 0.032359 in thorax parameters, has a RED value of 0.317137 in abdominal parameters, approaching lung tissue with a RED value of 0.3210 [16]. Meanwhile, polymer clay with variations of 4g mixed with metal powder Al_2O_3 has a RED value of 0.53188 on thorax and polymer clay parameters with a variation of 7g powder mixture Al_2O_3 has a RED value of 0.585415 in the head parameter, has a RED value of 0.581525 in the thorax parameter, and has a RED value of 0.580318 in the abdominal parameter. In polymer clay with variations of 8g mixed with metal powder (Al_2O_3) has a RED of 0.600799 in the head parameter, has a RED value of 0.660172 in the thorax parameter, and has a RED value of 0.601517 in the abdominal parameter. Polymer clay with a variety of 10g metal powder mixtures Al_2O_3 has a RED value of 0.783135 in the head parameter, has a RED value of 0.788554 in the thorax parameter, and has a RED value of 0.778165 in the abdominal parameter which is still far from being close to the tissue.

From the results of the Relative Electron Density (RED) value in Figure 2, you can see below the RED value for polymer clay mixed with metal powder Al_2O_3 0g in the parameters of the head, thorax, abdomen, it is close to the lung tissue (Inhale). At grade RED polymer clay with a mixture of metal powder Al_2O_3 1g on the head parameters and RED value of polymer clay with a mixture of metal powder Al_2O_3 4g in head and abdominal parameters it approaches lung tissue (Exhale). Meanwhile, the RED polymer clay value is mixed with metal powder Al_2O_3 1g pthere are thorax and abdominal parameters approaching lung tissue. Meanwhile, the RED polymer clay value is mixed with metal powder Al_2O_3 4g on thorax parameters and RED polymer clay values with a mixture of metal powder Al_2O_3 7g,8g, and 10g the parameters of the head, thorax, abdomen are not close to the tissue. Judging from the results of the CT Number (HU) and Relative Electron Density values from figures 1 and 2 with variations in the head, thorax and abdomen parameters using tube voltage and current of 120 kV and 199 mA at the head, 120 kV and 98 mA at the thorax, 120 kV and 147 mA in the abdomen has insignificant CT Number (HU) and Relative Electron Density (RED) values. This is due to the difference in density, the more metal powder there is Al_2O_3 polymer clay will have an increased density.

IV. Conclusion

Based on the research that has been carried out, it can be concluded that the results of the CT Number (HU) value of polymer clay mixed with metal powder Al_2O_3 0g, 1g, 4g, 7g, 8g, and 10g in the parameters of the head, thorax, abdomen, it is close to lung tissue (Inhale), lung tissue (Exlahe), skin tissue, soft tissue and fat tissue. Meanwhile, the results are from the Relative Electron Density (RED) value of polymer clay mixed with metal powder Al_2O_3 0g in the parameters of the head, thorax, abdomen, it is close to the lung tissue (Inhale). At grade RED polymer clay with a mixture of metal powder Al_2O_3 1g on the parameters of the head, thorax, abdomen and the RED value of polymer clay mixed with metal powder Al_2O_3 4g in head and abdominal parameters it approaches lung tissue (Exhale). But at the value of RED polymer clay with a mixture of metal powder Al_2O_3 4g on thorax parameters and RED polymer clay values with a mixture of metal powder Al_2O_3 7g, 8g, and 10g the parameters of the head, thorax and abdomen are not close to the tissue. From this research it is concluded that polymer clay can be used as a radiotherapy bolus material in a variety of metal powder mixtures Al_2O_3 with certain parameters and more powder Al_2O_3 d If you mix it with polymer clay, the CT Number (HU) and Relative Electron Density (RED) values obtained will increase.

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