Phi-TERA : Journal Physics in Teaching, Education Research and Application
Vol. 1, No. 1 [Juli 2024], pp. 29-36

Measurement of Surface Dose Increase in Radiotherapy Boluses Using Polymer Clay Material Mixed with Al_2O_3 Metal Powder

Kevin Sheva Kurniawan 1*
Program Studi Fisika, Fakultas Sains Teknologi dan Matematika, Matana University, Indonesia.
Email: kevin.sheva@student.matanauniversity.ac.id

Dwi Oktaviani 2
Program Studi Fisika, Fakultas Sains Teknologi dan Matematika, Matana University, Indonesia.
Email: dwio4375@gmail.com

Taat Guswantoro 3
Program Studi Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Kristen Indonesia, Indonesia.
Email: taat.guswantoro@uki.ac.id

Abstrak. Bolus is a means of radiotherapy which is made from material equivalent to tissue and is placed directly on the surface of the skin during the radiotherapy process. A bolus is used as a replacement for missing tissue or a flat surface in the direction of the radiation beam. The result is an even distribution of dose on the isodose curve. The material commonly used as a bolus is wax which is basically equivalent to tissue and has high strength. The aim of this research is to analyze the effect of Polymer Clay boluses on increasing surface dose and determine the characteristics of Polymer Clay boluses in terms of variations in bolus thickness. By looking at the detector dose value and comparing the bolus thickness variation graph with the Percentage Depth Dose (PDD) value. The modality used in this research is Linear Accelerator (LINAC). The bolus dose results can be seen from the Gading Pluit Hospital computer and transferred to Excel after that to obtain the graph using OriginPro software. It can be seen that there is an effect of the bolus of the polymer clay material with increasing surface dose, that is, with each increase in bolus thickness and increase in energy, the surface dose increases and when it reaches R100, the dose at the next thickness will decrease.

Keywords: Polimer clay, Bolus, Radioteraphy, Linear Accelerator, Percentage Depth Dose

I. Introduction

The type of cancer treatment that uses ionizing radiation is radiotherapy. This type of treatment was developed by considering the minimum dose to the organs at risk but can provide the greatest cancer effect. The percentage of surface cancer doses, such as breast cancer, has not yet reached its maximum point [1]. The dose curve shows the distribution of radiation doses received by the body, with the highest doses achieved far from the superficial cancer sites targeted for treatment.

The use of both radiation beams varies depending on the position of the cancer. If the cancer is on the surface of the skin or about 5 cm from the surface of the skin, cancer treatment can use electron radiation beams with energy in the order of mega electron volts (MeV). If the cancer is far from the surface of the skin, photon radiation beams with energies in the order of mega electron volts (MeV) are used [2].

One of the problems during the radiotherapy process using LINAC is that most of the radiation hits healthy tissue, which has the potential to cause new cancer (OARS). In treating cancer on the surface of the skin (superficial), bolus radiotherapy can solve this problem because the surface dose of the electron beam produced still does not reach 100%. In radiotherapy, a bolus is used for cancer that is in direct contact with the skin with the aim of increasing the surface dose to the skin surface area [3].

Bolus making has been carried out by several previous researchers from various basic materials such as Play-doh, wet cotton gauze and superflab. Measurements performed on known water Dmax for all bolus materials showed similar results for SuperFlab and Plastic Water with differences of less than 3% for most energies. Play-Doh produces more attenuation or less dose buildup compared to Plastic Water, especially at lower energies. The difference reached 24.7% for a beam energy of 5 MeV for Play-Doh. Evaluation of dose increase curves for all materials showed peak dose increases for Wet Cottan Gauze and Play-Doh occurred at lower thicknesses compared to Plastic Water and SuperFlab, particularly at lower energies. If Play-Doh and Wet Cottan Gauze are to be used for electron bolus material, a dose increment curve must be created for the machine used and an appropriate bolus material thickness must be selected based on that curve [4].

The ingredients for making boluses used by several researchers above are ingredients that are difficult to find in the community because of the presence of chemicals and require expensive costs to make boluses. However, there are other methods for making Polymer Clay with cheap and easily available ingredients, such as wood glue, corn starch, mineral oil, and lemon juice. Polymer Clay with this material can harden easily when left in the open air, so it doesn't need to be heated in the oven to harden it. Polymer Clay is an artificial soft material that is soft and flexible so it is very easy to shape.

This research was conducted to examine increasing surface dose in radiotherapy boluses using Polymer Clay and a mixture of Al_2O_3 metal powders. This study aims to show an increase in surface dose using a bolus made from Polymer Clay and a mixture of Al_2O_3 metal powders.

II. Method

This research was conducted at Gading Pluit Hospital in December 2023. This research method was to look for the PDD curve using a solid water phantom with an SSD of 100 cm and a field area of 10x10 cm. After that, the researchers measured the surface dose using a detector before using the bolus and after using the bolus. In this case, the variations in bolus thickness and phantom slab thickness are 0.5, 1 and 1.5 cm. The energy used in LINAC is 6.8 and 10 MeV. There are 2 boluses used, namely a bolus that does not use a mixture and a bolus that uses a mixture of $Al2O3$. After measuring the detector, the author obtained data on dose values for each parameter that had been measured and found R100 (the distance at which the dose reaches 100%).

The dose value data was analyzed using Excel to obtain the percentage value of increase in surface dose for each specified parameter. Researchers also carried out analysis using OriginPro 8.5 to obtain Percentage Depth Dose graphs for each variation in bolus thickness using the $Al2O3$ mixture or not using the mixture. In this case we can determine the effect of varying bolus thickness on increasing surface dose.

III. Result and Discussion

In calculating the percentage value of increase in surface dose, 2 boluses are used, namely a bolus without using a mixture and a bolus with a mixture of metal powder Al_2O_3. The purpose of using the two boluses is to be able to compare the surface dose value and the effect of the Al_2O_3 metal powder. Variations in the thickness of the Phantom Slab are also very important in this research because thickness is a factor in determining the R100. In the medical world, R100 is very necessary so that the dose received by the patient can be 100% in radiotherapy treatment. In this research, researchers also mixed polymer clay with a mixture of 4 grams of $Al2O3$ metal powder. Selection of 4 grams of aluminum powder produces a Houndsfield (HU) value that is close to body tissue. In this variation, it is used as a comparison factor against pure or unmixed boluses. The percentage value of increasing surface dose without using a slab phantom at an energy of 6 MeV can be seen from table 1.

Table 1. Percentage value of surface dose increase in bolus of $Al2O3$ powder mixture with varying thickness without using Slab Phantom at 6 MeV energy

Energy of 6 MeV	Without Slab Phantom		
Bolus A	Dose (pC)	Percentage (%)	Increase (%)
0	540,1	100	0
0,5	591,6	109,5352712	9,535271246
1	608	112,571746	12,57174597
1,5	605,8	112,164414	12,164414

It can be seen in table 1 that the percentage increase in surface dose from each thickness variation has varying values. At a thickness of 0.5 cm and 1 cm, the percentage increase in surface dose is high, but at a thickness of 1.5 cm, the percentage increase in surface dose decreases which is not very significant. So, the bolus thickness that has the highest percentage increase in surface dose is a bolus with a thickness of 1 cm with a percentage increase in surface dose value of 12.5%.

Table 2. Percentage value of surface dose increase in bolus of $Al2O3$ powder mixture with varying thickness without using Slab Phantom at 6 MeV energy

Energy of 6 MeV	Without Slab Phantom		
Bolus B	Dose (pC)	Percentage (%)	Increase (%)
0	540,1	100	0
0,5	629,4	116,5339752	16,53397519
1	638,2	118,1633031	18,16330309
1,5	653,8	121,0516571	21,0516571

In table 2, this is the percentage value of surface dose increase in a bolus of aluminum powder mixture with varying thicknesses without using a slab phantom at an energy of 6 MeV. From the data above, it can be compared with the data in table 1 to see the effect of the aluminum powder mixture on the bolus and the percentage increase in surface dose. It can be seen that at a bolus thickness of 0.5 cm – 1.5 cm the percentage value of increasing surface dose increases. From the data in tables 1 and 2, it can be compared that the percentage value of increasing surface dose and bolus thickness has changed, namely the percentage value has increased very significantly from 12.5% to 21%. Judging from the variation in thickness, it has also changed from a thickness of 1 cm to 1.5 cm. This shows the influence of the aluminum powder mixture which makes the surface dose higher.

Table 3. Percentage value of increase in surface dose in bolus with varying thickness without using Slab Phantom at an energy of 8 MeV

Energy of 8 MeV	Without Slab Phantom		
Bolus A	Dose (pC)	Pecentage (%)	Increase (%)
0	569,9	100	0
0,5	618,6	108,5453588	8,545358835
1	630,9	110,7036322	10,70363222
1,5	629,6	110,475522	10,47552202

Table 4. Percentage value of surface dose increase in a bolus of $Al2O3$ metal powder mixture with varying thicknesses without using Slab Phantom at an energy of 8 MeV

Energy of 8 MeV	Without Slab Phantom		
Bolus B	Dose (pC)	Percentage (%)	Increase (%)
0	569,9	100	0
0,5	648,2	113,7392525	13,7392525
1	656,2	115,1430075	15,14300755
1,5	664,4	116,5818565	16,58185647

It can be seen from the comparison of the percentage values for increasing surface dose in tables 3 and 4 that there has been a very significant change. Just like the change at 6 MeV energy, at 8 MeV energy there is also a change in the percentage value of increasing surface dose from 10.7% to 16.5% and a change in thickness from 1 cm to 1.5 cm.

Table 5. Percentage value of increase in surface dose in bolus with varying thickness without using Slab Phantom at an energy of 10 MeV

Energy of 10 MeV	Without Slab Phantom		
Bolus A	Dose (pC)	Percentage (%)	Increase (%)
0	596,2	100	0
0,5	642,1	107,6987588	7,698758806
1	652,6	109,4599128	9,459912781
1,5	651	109,1915465	9,191546461

Table 6. Percentage value of surface dose increase in bolus of $Al2O3$ metal powder mixture with varying thickness without using Slab Phantom at 10 MeV energy

Energy of 10 MeV	Without Slab Phantom		
Bolus B	Dose (pC)	Percentage (%)	Increase (%)
0	596,2	100	0
0,5	666,2	111,7410265	11,7410265
1	673,3	112,931902	12,93190205
1,5	679,7	114,0053673	14,00536733

From the data in tables 5 and 6 it can be seen that 10 MeV energy has a very significant difference in the percentage value of increasing surface dose. Thicknesses of 1 cm and 0.5 cm have a very high percentage increase in surface dose compared to other thicknesses. The comparison between the bolus using the aluminum powder mixture and without using the aluminum powder mixture experienced an increase in the surface dose percentage value, namely 9.4% to 14% and the thickness variation also changed, namely from 1 cm to 1.5 cm.

From the data above it can be seen that for each energy bolus without using a mixture, the surface dose decreases from a thickness of 1 cm to a thickness of 1.5 cm. This is because in the thickness range of 1 cm to 1.5 cm there is an R100 value which makes it reduction in surface dose values. The data for each energy in a bolus using a mixture of aluminum powder shows an increase in surface dose at each thickness, this is because the variation in thickness does not show any R100 which means there is no decrease in the surface dose value like a bolus without using a mixture.

This graph is to see the PDD (Percentage Depth Dose) value at each depth of the Fantom Slab with dose data on variations in bolus thickness with a mixture of $Al2O3$ metal powder and without using $Al2O3$ metal powder. This graph can be obtained using OriginPro Software version 8.5.

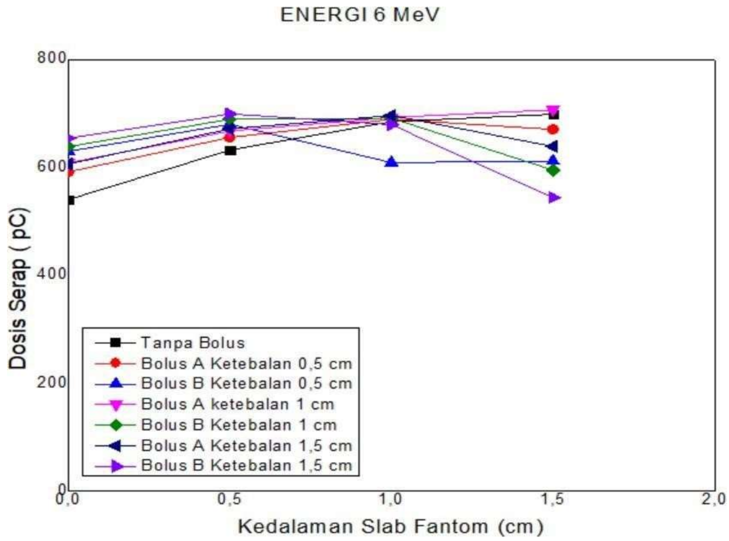

Figure 1. Graph of the absorbed dose value into the Fantom Slab at an energy of 6 MeV

At an energy of 6 MeV the R100 value in Fantom water is 1.3 cm [5]. You can see R100 for each bolus thickness without mixture or using mixture. At the surface dose the researchers obtained R100 at a depth of 1 cm, at a bolus thickness of 0.5 cm without using the R100 aluminum powder mixture it was around 1 cm, at a bolus thickness of 0.5 cm using the R100 aluminum powder mixture it was around 0.5 cm .

At a bolus thickness of 1 cm without using R100 aluminum powder it is around 1 cm, at a bolus thickness of 1 cm with a mixture of R100 aluminum powder it is around 1 cm, at a bolus thickness of 1.5 without using R100 aluminum powder it is around 1 cm and at a thickness of a 1.5 cm bolus mixed with R100 aluminum powder is around 0.5 cm.

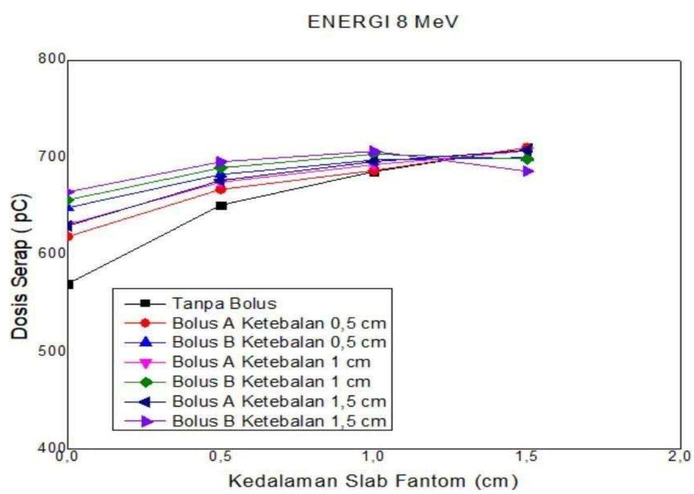

Figure 2. Graph of the absorbed dose value into the Fantom Slab at an energy of 8 MeV

At an energy of 8 MeV the R100 value in Fantom water is 1.7 cm [6]. You can see R100 for each bolus thickness without mixture or using mixture. At the surface dose the researchers obtained R100 at a depth of 1.5 cm, at a bolus thickness of 0.5 cm without using a mixture of aluminum powder R100 was around 1.5 cm, at a bolus thickness of 0.5 cm using a mixture of aluminum powder R100 was around 1.5 cm.

At a bolus thickness of 1 cm without using R100 aluminum powder it is around 1.5 cm, at a bolus thickness of 1 cm with a mixture of R100 aluminum powder it is around 1 cm, at a bolus thickness of 1.5 without using R100 aluminum powder it is around 1.5 cm and at a bolus thickness of 1.5 cm with a mixture of R100 aluminum powder it is around 1 cm.

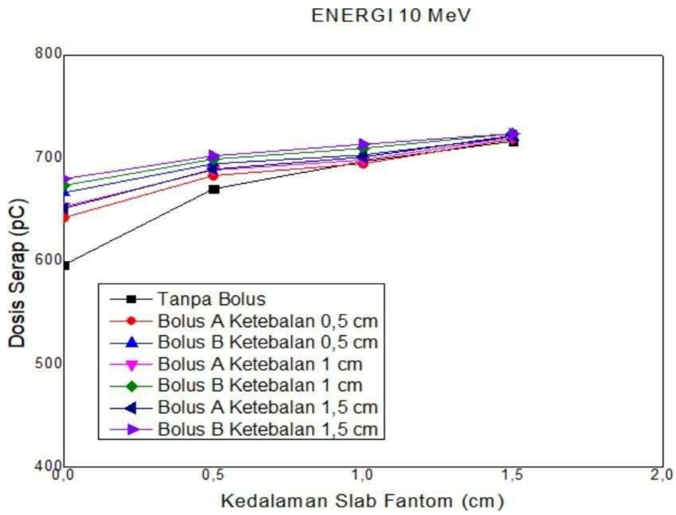

Figure 3. Graph of the absorbed dose value into the Fantom Slab at an energy of 10 MeV

At an energy of 10 MeV the R100 value in Fantom water is 2.1 cm [7]. At an energy of 10 MeV, it can be seen in the picture that the R100 value is not visible because the R100 in the water phantom has a value of 2.1 cm, whereas the thickness variation in this study only reached 1.5 cm.

The decrease in surface dose value for each increase in energy is related to the presence of stopping power. Stopping power is the stopping power of a medium which can be defined as the average unit of energy loss experienced by charged particles per unit path length in the medium under consideration. Instead, when there is an increase in energy, the stopping power will be smaller because the greater the energy, the greater the penetrating power and the less energy absorbed by the medium. This causes a decrease in the surface dose value for each increase in energy. This decrease in surface dose value can also be seen from the PDD curve because the greater the energy, the smaller the build up produced.

IV. Conclusion

Based on the research that has been carried out, it can be concluded that there is an effect of a bolus made from polymer clay with an increase in surface dose in radiotherapy, that is, with each increase in bolus thickness and each increase in energy, the surface dose decreases due to the presence of stopping power which is related to the absorbed dose of the bolus. and when it reaches R100, the dose at the next thickness will decrease further. The characteristics of the bolus can also be seen from the thickness of each bolus. It can be seen that the bolus without a mixture can have the highest dose increase percentage value at a thickness of 1 cm and the bolus containing a mixture of $Al2O3$ metal powder has the highest dose increase percentage value at a thickness of 1.5 cm. any energy and the influence of the metal powder mixture which makes the surface dose higher.

References

[1] Asrisal R, Dewang S, Tahir D dkk. ElektronBeam of Linear Accelerator Have Been Verified With. Published online 2015:1-6.
[2] Faiz M. Khan, PhD Professor, John P. Gibbons P. The Physics Of Radiation Therapy. 5th ed.; 2014.
[3] E.B. Podgorsak. Physics: 2005, Radiation Oncology Students, A Handbook for Teachers and Student2005.
[4] Heri S, Eko H, Gede JW, Santi. AY, Suparman Suppa Astri SS. Bolus Berbahan Silicone Dan Natural Rubber.; 2018.
[5] Seppälä T, Collan J, Auterinen I dkk . 2004. A dosimetric study on the use of bolus materials for treatment of superficial tumors with BNCT.;61(5):787-791. doi:10.1016/j.apradiso.2004.05.054

[6] Taat Guswantoro, Astri Suppa Supratman, Imelda Sakti Asih. 2020. Karakterisasi Alginat Sebagai Bahan Setara Dengan Jaringan Lunak Untuk Radioterapi :Jurnal Pendidikan, Matematika dan Sains.
[7] Muslimah Putri Utami,Sugiyanto dkk. 2021. Pembuatan Media Bolus Berbahan dasar Bubuk Eichhornia Crassipes (Eceng Gondok) Untuk Penyinaran Radioterapi: Elesevier
[8] Tarigan, Kerista Sembiring, Timbangen. 2019. Pembuatan dan Penentuan Absorben Bolus Radioterapi Berbahan Alginat Menggunakan Energi 8 MeV dan 10 MeV : The University Institutional
[9] Endarko,Siti Aisyah dkk. 2021. Evaluation of Dosimetric Properties of Handmade Bolus for Megavoltage Electron and Photon Radiation Therapy : Journal of Biomedical,Physics and Engineering.
[10] Giovanna Dipasquale,Alexis Poirer dkk. 2018. Improving 3D-printing of megavoltage X-rays radiotherapy bolus with surface-scanner : Journal Biomedcentral.
[11] Dwi Bondan Panular. Perbandingan Hasil Pengukuran Parameter Berkas Sinar-X dan Elektron Keluaran Pesawat LINAC Menggunakan Detektor Matriks dan Fantom Air.; 2012
[12] Suharni S, Kusminarto K dkk. 2013. Analisis Hasil Pengukuran Percentage Depth Dose (PDD) Berkas Elektron Linac Elekta RSUP Dr. Sardjito. Prosiding Pertemuan dan Presentasi Ilmiah Teknologi Akselerator dan Aplikasinya.
[13] Lori Young, Landon Wootton dkk. 2019. Dosimetric effects of bolus and lens shielding in treating ocular lymphomas with low-energy electrons : Science Direct
[14] Bilalodin, Abdullatif Farzand. 2022. Modeling and Analysis of Percentage Depth Dose (PDD) and Dose Profile of X-Ray Beam Produced by Linac Device with Voltage Variation : Jurnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)
[15] Junaedi D, Setiawati E, Arifin Z, et al. Analisis Penggunaan Polydimethyl Siloxane Sebagai Bolus Dalam Radioterapi Menggunakan Elektron 8 Mev Pada Linac. 2016;5(4):391-398.