Original Research Article

Compliance Test of Percentage Depth Dose (PDD) Using LINAC Machine Brand Electa Precise Against American Association of Physicists in Medicine (AAPM) PDD With Electron Beam Energy Variation at Radiotherapy Installation RSUP Prof. Ngoerah in Denpasar

Abstract

The purpose of the study was to determine the value of PDD against energy variations in the electron beam using the Elekta Precise Brand LINAC aircraft, and to determine the suitability of the PDD value against energy variations in the electron beam with the standards set by AAPM. PDD value data obtained from the results of research using Sun Nuclear Dosimetry Software (SNC Dosimetry). The results of the study will then be compared with the standard value at AAPM, which is a maximum of 2%. From the deviation value of each 4 MeV energy of 1.1% - 1.8%, 6 MeV energy of 1.1% - 1.6%, and 8 MeV energy of 1.0% - 1.2%, the deviation error at 4, 6, and 8 MeV energy is in accordance with the tolerance limit set by AAPM which is 2%. So that the Elekta Precise LINAC machine at the Radiotherapy Installation of Prof. Ngoerah Denpasar Hospital is feasible to operate to receive patients.

Keywords: LINAC, Electron, Energy, PDD, Deviation.

1. Introduction

The Linear Accelerator (LINAC) is a system (machine) that is used to accelerate charged particles through a straight line (linear) with high-frequency electromagnetic waves that can produce photon beams (X-rays) and electron beams that are used to kill tumor and cancer cells in treatment with radiotherapy [1]. LINAC is a device that uses high-frequency electromagnetic waves to accelerate charged particles such as high-energy electrons through a linear tube designed to accelerate the linear movement of electrons so as to produce photon and electron beams. Photon beams have energies of 6 MV and 10 MV, while electron beams have energies of (4, 6, 8, 10, 15, and 18) MeV [2]. Percentage Depth Dose (PDD) is the ratio of the absorbed dose at a specific depth to the absorbed dose at the maximum depth. PDD is very important in radiotherapy planning because it helps doctors and radiation specialists in determining the right dose of radiation that should be given to patients with cancer. In radiation therapy, the correct dose of radiation is very important to ensure that the cancer cells are destroyed safely and minimally damage the surrounding healthy tissue. PDD measurement is very important due to the calculation of the right dose and irradiation time [3].

1.1 Radiotherapy

Radiotherapy is a medical procedure that uses ionizing radiation to kill cancer cells as much as possible while minimizing damage to normal cells [4]. The dose given to the target organ in radiotherapy must be precise by trying to keep the dose to other parts of the body as low as possible. Excessive doses will endanger the patient, while low doses will also affect the patient's healing [5]. There are two methods of radiotherapy, namely brachytherapy and external radiation or teletherapy. Brachytherapy (close-range radiation) is a radiation therapy method that places the radiation source near the target area. Meanwhile, the use of a radiation sources in a certain distance from the body, called teletherapy. External therapy includes radiation therapy that uses Co-60 therapy machines, Linear Accelerators (LINAC), Cs-137 therapy machines, and so on [6].

1.2 Linear Accelerator (LINAC) Machine

The Linear Accelerator, commonly referred to as LINAC, employs high-frequency electromagnetic waves to propel charged particles such as high-energy electrons in a linear tube. This device can be utilized to treat tumors located near the surface of the body with the high-energy electron beam, or by colliding the electrons with a target to produce X-rays that can be utilized to treat tumors located deeper within the body [7]. LINAC was first introduced by R. Wideroe in Switzerland in 1929 [8]. The ionization process resulting from the interaction of ionizing radiation (photon and electron beams) with matter (cancer) will cause the deoxyribose nucleic acid (DNA) chain of cancer to be disrupted, thereby killing the cancer tissue. The amount of monitor units (MU) needed as input is influenced by various factors such as the desired dose size, the depth of the cancer, the reference dose rate or calibration of the monitor, the collimator setting size, the size of the cancer field, and other variables [9, 10].

1.3. Percentage Depth Dose (PDD)

Percentage Depth Dose (PDD) was the ratio of the absorbed dose at a certain depth (D_d) to the absorbed dose at the maximum depth (D_{max}). The equation for calculating PDD is as follows: [11]

$$\text{PDD} = \left(\frac{D_d}{D_{max}}\right) \text{ x } 100\% \quad (1)$$

Information:

D_d = absorbed dose at a certain depth (Gy)

D_{max} = absorbed dose at maximum depth (Gy)

The maximum dose (D_{max}) of the given dose can be seen in Equation 2:

$$D_{max} = \left(\frac{D_d}{PDD}\right) \text{ x } 100\% \quad (2)$$

PDD is D_d/D_{d0} where D_d at the desired depth and D_{d0} is the reference depth at the maximum dose. The distribution of doses on the principal axes in the patient or phantom known as the PDD, is generally normalized to the maximum dose (D_{max}) = 100%, the dose at maximum depth (D_{max}).

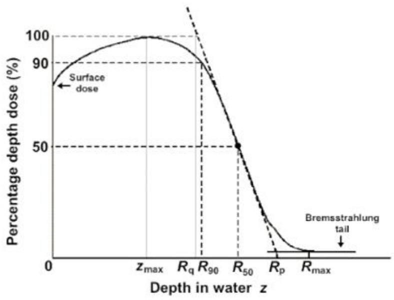

Figure 1 Typical electron beam PDD curve of R_q, R_p, R_{max}, R_{50} and R_{90}.

Based on Figure 1 z_{max} is the greatest penetration depth of electrons in the absorbing medium. R_p is the depth where the tangent plotted through the steepest part of the dose curve is the electron depth tangent to the extrapolated line from the bremsstrahlung tail. The depth of R_{90} and R_{50} is the depth of the PDD electron curve where the depth exceeds the maximum depth (z_{max}) achieved at PDD values of 90% and 50% respectively [12].

1.4 Dosage Absorb Radiation

Absorbed dose is the amount of energy absorbed by a material (including the human body) that is exposed to radiation, and is one of the most basic physical quantities to determine the effect of radiation on matter. The SI unit of absorbed dose is Joule/kg or the same as gray (Gy) [13]. Absorbed dose is the amount of energy provided by direct or indirect ionizing radiation. The absorbed dose in relation to the amount of energy given is defined as the average energy E received by a material with mass m in volume V caused by ionization of certain radiation which is expressed by Equation 3 [14].

$$D = \frac{dE}{dm} \tag{3}$$

Information:

D = dose absorption (J/kg or Gy)

dE = energy (joules)

dm = massa (kg)

2. Research Methods

This study used a water phantom as a substitute for patients at the Radiotherapy Installation of Prof. Ngoerah Hospital. The stages of this research are as follows: first, prepare the tools and materials used. Second, set up a water phantom, field size of 10 cm x 10 cm and an ionization chamber detector placed in the middle of the phantom. Third, install the 10 cm x 10 cm applicator on the gantry. Fourth, connect the PC that has the dosimetry application installed to the water phantom using a PDI cable. Fifth, set up the dosimetry application with energy and depth setup. Sixth, set the energy of 4 MeV on the console computer and a depth of 0 cm – 20 cm. Seventh, collect PDD data. Finally, repeat with (6, 8, 10, and 15) MeV energys.

3. Data Analysis

The data used is primary data by measuring directly the magnitude of the PDD value generated on the LINAC Elekta Precise machine in the Radiotherapy Installation of Prof Ngoerah Hospital. PDD value data obtained from measurement results using Sun Nuclear Dosimetry (SNC Dosimetry) Software. The measurement results will then be compared with the standard value on the AAPM, which is a maximum of 2%.

To find out whether the measurement value for the reference obtained exceeds a predetermined limit or not, a statistical test is carried out, namely a one-way T-test using SPSS version 26 software. The test is carried out with a 95% confidence level or a significance level of 0.05, with the following hypotheses:

H_0: There is no difference the energy variation values of the electron beam and the PDD that has been determined.

H_1: There is a difference between the values of the energy variations of the electron beam and the PDD that have been determined.

From the results of the statistical test, namely the level of significance obtained will be compared. If the significance level is greater than 0.05 then H_0 is accepted and H_1 is rejected, if the significance level is less than 0.05 then H_0 is rejected and H_1 is accepted. From these results it can be determined the PDD value with energy variations against the provisions of the AAPM in the Radiotherapy Installation of RSUP. Prof Ngoerah, is it in accordance with the provisions of AAPM.

4. Result and Discussion

In this study, we will look for the PDD value and the R value where the R value is the output value of the PDD where R_p is the depth where the tangent line is plotted through the steepest part of the electron depth dose curve. The R_{100} value is the maximum depth value, the R_{90} and R_{50} values are the depth in the PDD electron curve where the depth exceeds the maximum depth (z_{max}) achieved at PDD values of 90% and 50% respectively.

The measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P along with references are shown in Table 1.

Table 1 : Measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P along with references

Energy (MeV)	Position	Depth (cm)		Deviation (%)
		Research	Reference	
4	R100	0,881	0,893	1,322
	R90	1,189	1,212	1,898
	R85	1,279	1,298	1,464
	R80	1,350	1,369	1,388
	R50	1,685	1,706	1,231
	Rp	1,916	1,938	1,135
6	R100	1,266	1,286	1,555
	R90	1,809	1,834	1,363
	R85	1,928	1,948	1,027
	R80	2,035	2,059	1,166
	R50	2,460	2,501	1,639
	Rp	2,915	2,949	1,153
8	R100	1,620	1,646	1,580
	R90	2,383	2,414	1,284
	R85	2,525	2,552	1,058
	R80	2,640	2,668	1,049
	R50	3,205	3,242	1,141
	Rp	3,850	3,890	1,028

The results of the calculation of the deviation are shown in Table 1 where the result is that the deviation is still within the tolerance limit set by AAPM, which is 2%.

Based on the table above, it is said to have been normally distributed, then a one-way t-test (One Sample t-test) was carried out to find out whether there were significant differences or not in accordance with the established AAPM standards. The data tested statistically are research data R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P with reference data R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P.

Table 2. The p value of the t-test test for each energy.

No.	Energy (MeV)	*p value*
1	4	0,00
2	6	0,00
3	8	0,00
4	10	0,00
5	15	0,00

Based on the results of the one-way t-test (One Sample t-test) in Table 2, it produces a p value $\leq$ 0.05, namely 0.00. Based on the established hypothesis, there is a difference between the energy variation values of the electron beam and the PDD that has been determined.

Based on Table 1, it can be made into a graph as shown in Figures 2 to 4, which is a graph of the measurement values of the measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and references to energys of 4 MeV, 6 MeV, and 8 MeV.

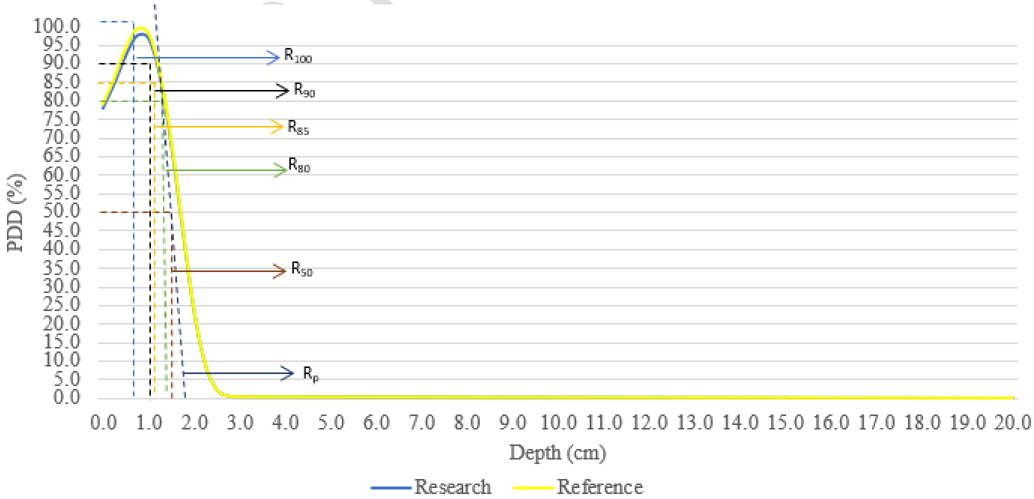

Figure 2 Graph of measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and references to 4 MeV energy.

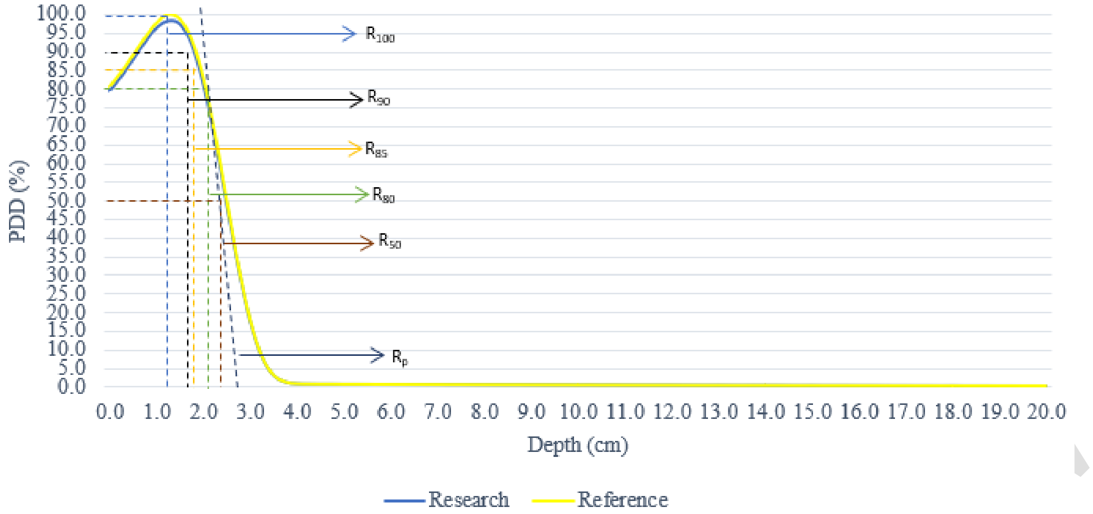

Figure 3 Graph of measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and references to 6 MeV energy.

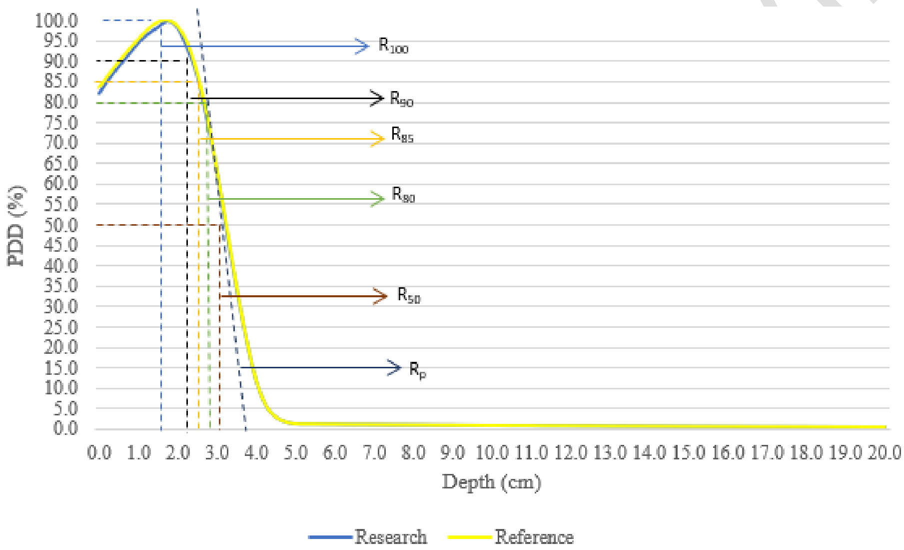

Figure 4 Graph of measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and references to 8 MeV energy.

From the research results in Table 1 it can be seen that the energy of 4 MeV for the position parameters R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P are 0.881 cm, 1.189 cm, 1.279 cm, 1.350 cm, 1.685 cm and 1.916 cm. At 6 MeV energy for the position parameters R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P are 1.266 cm, 1.809 cm, 1.928 cm, 2.035 cm, 2.460 cm and 2.915 cm. At 8 MeV energy for the position parameters R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P are 1.620 cm, 2.383 cm, 1.525 cm, 2.640 cm, 3.205 cm and 3.850 cm. It can be seen in each 4 MeV energy of 1.1% - 1.8%, 6 MeV energy of 1.1% - 1.6%, 8 MeV energy of 1.0% - 1.2. The error deviation at 4 MeV, 6 MeV, and 8 MeV is in accordance with the tolerance limit set by AAPM, which is 2%. So that the LINAC Elekta Precise machine at the Radiotherapy Installation of Prof. Ngoerah Hospital is eligible to operate to receive patients.

5. Conclusion

Based on the results and discussion it can be concluded that the deviation value of each 4 MeV energy is 1.1% - 1.8%, 6 MeV energy is 1.1% - 1.6%, and 8 MeV energy is 1.0% - 1 .2%, the error deviation at 4 MeV, 6 MeV, and 8 MeV is in accordance with the tolerance limit set by AAPM, which is 2%. So that the LINAC Elekta Precise aircraft at the Radiotherapy Installation of RSUP.Prof. Ngoerah Hospital is eligible to operate receiving patients.

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