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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

Naumi Paramita Putri Monicasari [a], Ni Nyoman Ratini [a], I. Wayan Balik Sudarsana [b], Ida Bagus Made Suryatika [a], Ir. Putu Suardana [a], I. Gusti Agung Widagda [a], Anak Agung Ngurah Gunawan [a*] and Rozi Irhas [b]

[a] *Department of Physics, Udayana University, Bali, Indonesia.*
[b] *Central General Hospital Prof. Dr. I. G. N. G. Ngoerah, Denpasar, Bali, Indonesia.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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**Corresponding author: E-mail: a.a.ngurahgunawan@unud.ac.id;*

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 Tolerance value set by AAPM of a maximum of 2%. From 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 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 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. The photon beams used in therapy are energies of 6 MV and 10 MV, and for electron beams used in therapy are 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 planning radiotherapy because it helps doctors and radiation specialists in determining the right dose of radiation to be given to the patient. In radiation therapy, the correct dose of radiation is very important to ensure that the cancer cells are destroyed and minimally damage the surrounding healthy tissue [3].

1.1 Radiotherapy

Radiotherapy is a treatment action using ionizing radiation sources as an effort to kill or stop the reproductive ability of tumor cells in the patient's body, accompanied by efforts to limit damage to healthy tissues in the radiation field so as not to interfere with the quality of life of patients. radiation field so that it does not interfere with the patient's quality of life [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 is a radiation therapy method that places the radiation source near the target area. While the use of radiation sources within a certain distance from the body is called teletherapy. External therapy includes radiation therapy using Co-60 therapy machines, Linear Accelerators (LINAC), Cs-137 therapy machines, and so on. [6].

1.2 Linear Accelerator (LINAC) Machine

Linear Accelerators use 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 [7,8]. 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) is 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]

$$PDD = \left(\frac{D_d}{D_{max}}\right) \times 100\% \qquad \text{(Leung, 2012)} \quad (1)$$

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:

$$D_{max} = \left(\frac{D_d}{PDD}\right) \times 100\% \qquad (2)$$

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}).

Based on Fig 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].

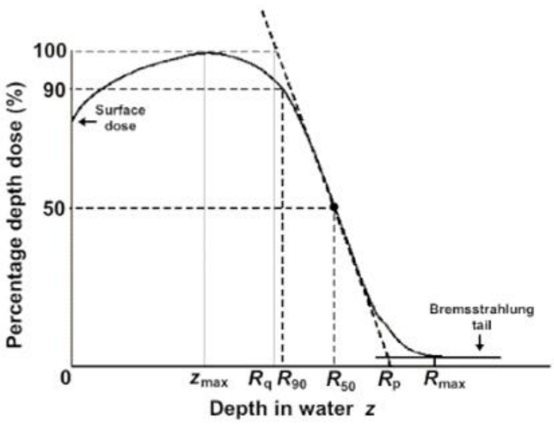

Fig. 1. Typical electron beam PDD curve of R_q, R_p, R_{max}, R_{50} and R_{90} (Podgorsak, 2003)

1.4 Radiation Absorbed Dose

Absorbed dose is the amount of energy provided by ionization direct or indirect 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].

$$D = \frac{dE}{dm} \qquad (3)$$

Information:

D = dose absorption (J/kg or Gy)
dE = energy (joules)
dm = massa (kg)

2. METHODOLOGY

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 SNC 125c 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 results of the study will then be compared with the standard Tolerance value set by AAPM of 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. RESULTS AND DISCUSSION

In this study, we will look for the PDD value and the R value 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 the values set by AAPM are shown in Table 1.

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 1, 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.

Based on the results of the one-way t-test (One Sample t-test) in Table 2, it produces a p value ≤ 0.05, namely 0.00.

Based on the results of Table 1, it can be represented in a graph, 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 with the values set by AAPM to energys of 4 MeV, 6 MeV, and 8 MeV .

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

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. From 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 deviation error at 4, 6, and 8 MeV energy is in accordance with the tolerance limit set by AAPM which is 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 in the Radiotherapy Installation of Prof. Hospital. Ngoerah is suitable for patient therapy.

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

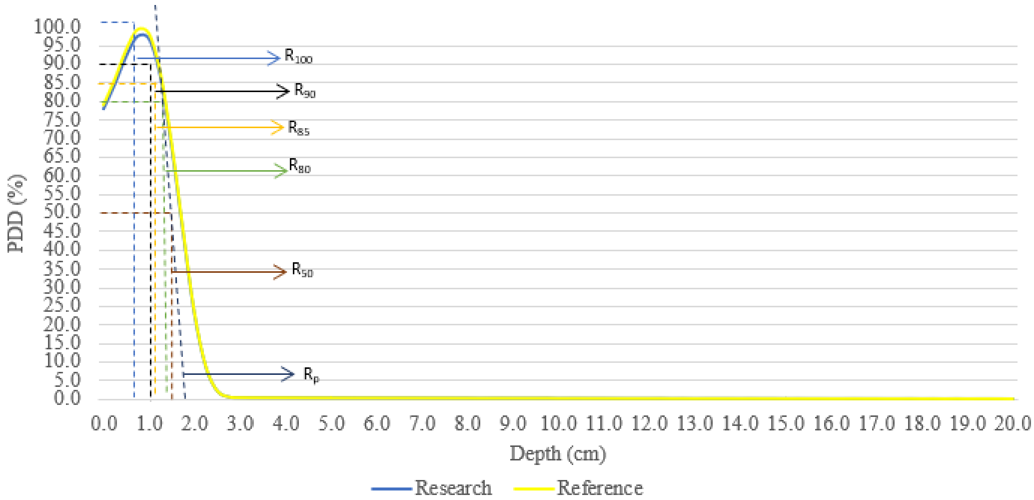

Fig. 2. Graph of measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and with the values set by AAPM to 4 MeV energy

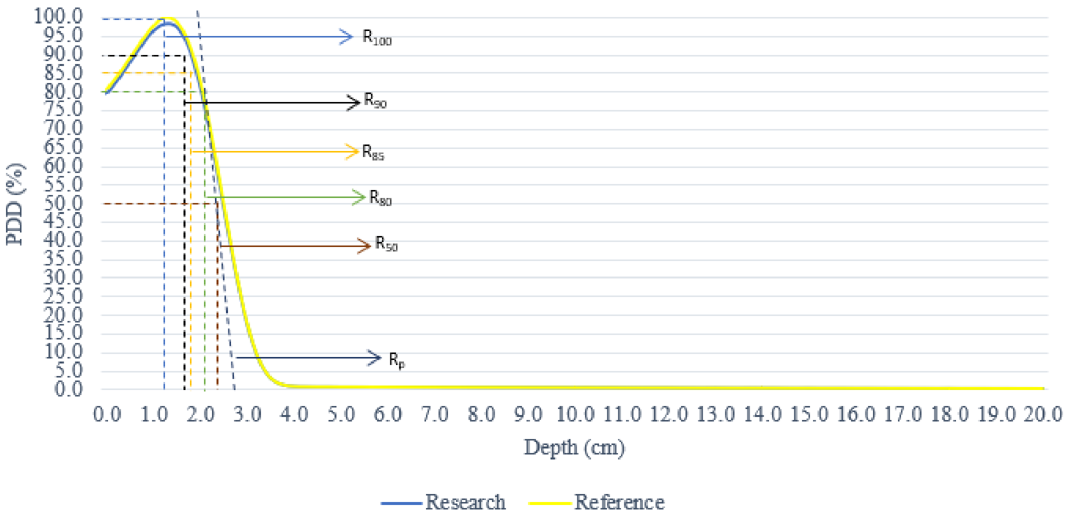

Fig. 3. Graph of measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and with the values set by AAPM to 6 MeV energy

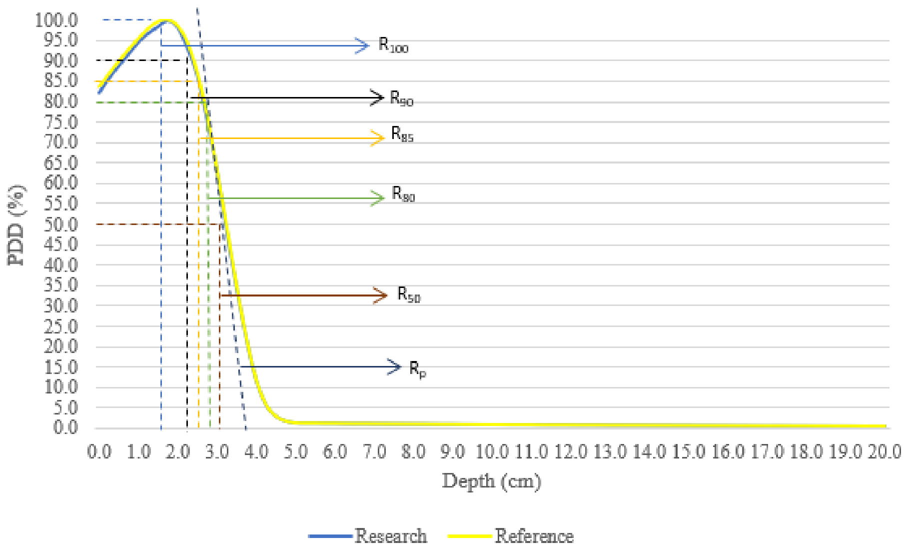

Fig. 4. Graph of measurement results of R_{100}, R_{90}, R_{85}, R_{80}, R_{50}, and R_P and with the values set by AAPM to 8 MeV energy

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.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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