

## Measurement of Percentage Depth Dose (PDD) for 6 MeV in water phantom and homogenous actual planning

Manwar A. AL-Naqqash<sup>1</sup>, Samar I. Essa<sup>2</sup>, Raghdah H. Hasan<sup>2</sup>

<sup>1</sup>Department of Surgical, College of Medicine, University of Baghdad

<sup>2</sup>Department of Physics, College of Science, University of Baghdad

E-mail: samaroem78@yahoo.com

### Abstract

Radiotherapy is the branch of clinical medicine concerned with the application of ionizing radiation in the treatment of disease. And it is used to killing of cancer cells in a tissue using ionizing radiation while keeping the sparing of healthy cells at acceptable level. X-ray beams are used to deposit absorbed dose at depth within a patient at the site of the tumor. The aim of this work is studying the relationship between the depth dose and the field size in water phantom and homogenous actual planning. In our work, the dose distribution at different depths (zero-18 cm) deep at 1cm interval treated with field size (10×10 and 20×20) cm<sup>2</sup> were studied. Results show that high similarity between water phantom and actual planning for this reason water is taken as phantom for Quality Assurance (QA) and calculation the depth dose. When increasing the field size, the percentage of surface dose increases that this could be caused by an increase of the amount of scattering in the larger fields. Conclusion: There is almost no difference in depth dose between homogenous planning and water phantom.

### Key words

High photon energy, water phantom, actual planning, depth dose.

### Article info.

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## قياس نسبة الجرعة العميقة (PDD) للطاقة (6 MeV) لوسط مائي مع التصميم العلاجي

### الحقيقي المتجانس للمرضى

منور عبدالاله النقاش<sup>1</sup>، سمر عمران عيسى<sup>2</sup>، رغبة حارث حسن<sup>2</sup>

<sup>1</sup>فرع الجراحة، كلية الطب، جامعة بغداد

<sup>2</sup>قسم الفيزياء، كلية العلوم، جامعة بغداد

### الخلاصة

العلاج الإشعاعي هو فرع من فروع الطب السريري المعنية بتطبيق الإشعاعات المؤينة في علاج المرضى. ويستخدم الإشعاع المؤين لقتل الخلايا السرطانية في الأنسجة مع الحفاظ على الخلايا السليمة عند مستوى مقبول. ويستخدم شعاع الأشعة السينية لترسيب الجرعة الممتصة في العمق داخل المريض في موقع الورم. الهدف من الدراسة هو دراسة العلاقة بين جرعة العمق والحجم في الوسط المائي والتصميم العلاجي المتجانس للمرضى تم دراسة توزيع الجرعة في أعماق مختلفة (0 - 18 سم) وللحجم (10 × 10 و 20 × 20) سم<sup>2</sup>. أظهرت النتائج التشابه الكبير بين الوسط المائي والتصميم العلاجي للمرضى لذلك تم استخدام الماء لحساب جرعة العمق. عند زيادة الحجم فان نسبة جرعة الأشعة تزداد على السطح وهذا يمكن أن يكون ناجما عن زيادة كمية تشتت الأشعة في الاحجام الكبيرة. من هذا البحث تم الاستنتاج انه لا يوجد تقريبا أي فرق في جرعة العمق بين التخطيط الفعلي المتجانس للمرضى والوسط المائي.

## Introduction

Radiotherapy is therapy using ionizing radiation in order to deliver an optimal dose of either particulate or electromagnetic radiation to a particular area of the body with minimal damage to normal tissues. The source of radiation may be outside the body of the patient (external beam irradiation) or it may be an isotope that has been implanted or instilled into abnormal tissue or a body cavity [1].

There are many objectives to using external radiotherapy in cancer treatment using high radiation doses from photon or electron beams. One of these radiotherapy machines is the linear accelerator (LINAC) which is the most commonly used for external beam radiation treatments for patients with cancer [2].

External beam therapy normally uses megavoltage linear accelerators to deliver a treatment beam high-energy photons, with an increasing energy of these radiations, the penetration power of photons and secondary electrons will be increased and as a result the point of maximum dose is placed in more depth [3]. Depending on the amount of energy, dose build up region occurs for x-rays megavoltage [4].

In radiotherapy, quality of a radiation beam is most usefully expressed in terms of its penetrating power, which is a function mainly of the mean photon energy, and may be fully described by its depth dose characteristics in water but an increase in surface dose with field size is also noted due to electron scattering from intervening materials [5].

The fundamental physical quantity of interest for relating radiation treatment to its outcome is the absorbed dose. Basic data of dose distributions usually derive from measurements in phantoms, and then use in a dose calculation system devised to predict dose distribution in

an actual patient [6]. These phantoms are tissue equivalent and are made of different materials and different methods. Dosimetry is a very significant element of radiotherapy treatment as all the treatment planning is based on the data obtained during dosimetry. Optimization of treatment plan, and calculation of dose for certain plan is performed when radiation physicist have measured dosimetry data [7].

Absorbed dose in the body is dependent on depth, field size, beam energy and source to surface distance (SSD). Measurement of absorbed dose is performed using water phantom [8, 9].

## Methods

This work was carried out in the Oncology Department Baghdad Teaching Hospital, Medical City/ Baghdad. Measurements were made Elekta linear accelerator, in the period between February and July (2017). Medical linear accelerator at 6MeV x-ray energy. The depth dose was measured between (0-18) cm deep at 1cm intervals. Measurements were performed with radiotherapy field sizes of 10 cm × 10 cm and to 20 cm × 20 cm and a 100 cm SSD.

Water is the standard phantom material for dosimetry measurements of photon and electron beams, distilled water as phantom material was used, about 180 liters of distilled water was pumped to fill the blue phantom reservoir. Pure distilled water was used in the experiment as the undistilled water contains different concentrations of natural contaminants such as traces of salts minerals containing iron, magnesium, calcium and many other elements so for accurate measurements it is preferable to use distilled water.

Water phantom is usually used for measuring basic dose distribution, because of its similarity to human soft

tissue due to its similar density, average atomic number and number of electrons per gram and universally available with reproducible radiation properties. The water tank (phantom) is large enough to allow full photon scatter.

### Measurement of Percentage Depth Dose (PDD)

In this measurement, the motorized water phantom was placed on the lift table and the set up was left under the gantry, Fig. 1. The tank was filled with distilled water up to the required mark and used as a phantom. The distance from the source to the surface of the water SSD was adjusted by the use of the remote control to 100 cm. The

levelling frame with a cross mark on it was moved on the water surface so that the midpoint of the cross mark adjusted to coincides with the water surface. The ionization chamber was fixed into the water phantom such that the sensitive part coincides with the water surface for our first measurement (that is; at 100 cm SSD) the ionization chamber can be moved through the water phantom along the central axis. A scan length of 1 cm and all necessary parameters for the field including the field size were entered in the basic setting. This setting permits the dose to be recorded after every 1cm increase in depth of travel of the ionization chamber along the central axis.



*Fig.1: Phantom was filled with distilled water.*

### Results

Percent depth dose data used for the evaluation accuracy of absorbed dose by using ionization chamber and placing it inside the water phantom. The required measured data of percentage depth dose were collected

for depths of (0-18) cm deep at 1cm interval in the phantom and actual planning, using field sizes of (10×10 and 20×20) cm<sup>2</sup>.

Table 1 shows the percentage depth dose distributions versus depth for energy 6 MeV, field size (10×10) cm<sup>2</sup>.

**Table 1: PDD of water phantom and actual planning for (6 MeV), field size (10×10) cm<sup>2</sup>.**

Field size (10×10) cm <sup>2</sup>		
Depth (cm)	Water phantom	Actual planning (homogenous)
0	47.62	42.1
1	96.03	96.5
2	99.12	99.1
3	95.30	94.7
4	91.16	90.2
5	87.11	85.8
6	83.19	81.7
7	79.16	77.6
8	75.42	73.6
9	71.71	69.9
10	68.26	66.6
11	64.90	63.1
12	61.55	59.8
13	58.44	56.7
14	55.53	53.6
15	52.72	50.5
16	49.98	47.6
17	47.46	45
18	45.07	42.5

The change of depth dose with (20×20) cm<sup>2</sup> field size was shown in Table 2.

**Table 2: PDD of water phantom and actual planning for (6MeV), field size (20×20) cm<sup>2</sup>.**

Field size (20×20)cm <sup>2</sup>		
Depth (cm)	Water phantom	Actual planning (homogenous)
0	54.75	46.3
1	97.41	97.4
2	99.21	98.9
3	95.70	94.9
4	92.10	90.9
5	88.41	86.8
6	84.77	83
7	81.24	79.2
8	77.72	75.5
9	74.40	72.1
10	71.20	69
11	68.07	65.8
12	64.91	62.7
13	62.01	59.7
14	59.24	56.8
15	56.60	53.8
16	53.88	51
17	51.47	48.4
18	49.01	45.9

The decrease in PDD with depth for all field sizes, is related to progressive

attenuation with depth and the inverse square law. Figs. 2 and 3.

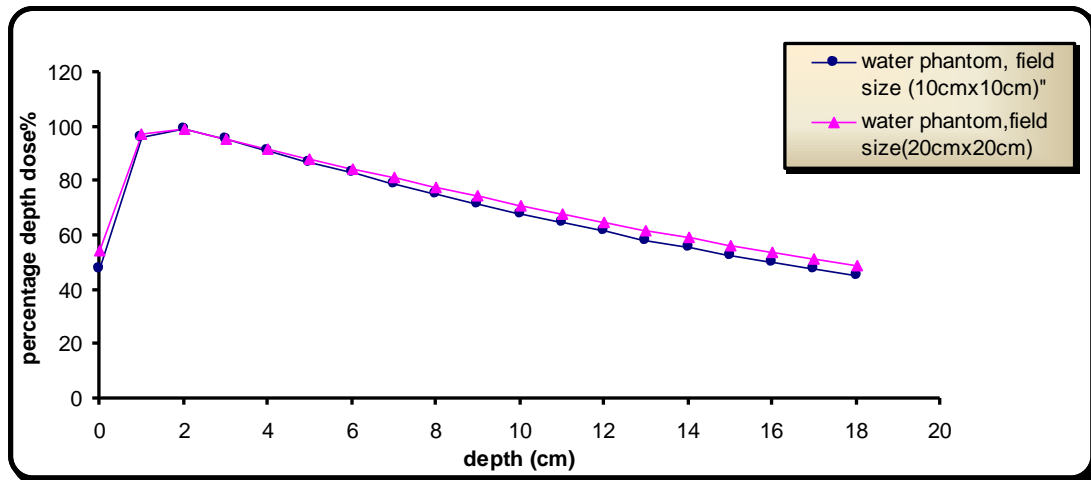


Fig. 2: The change of depth dose % with different depths of water phantom and actual planning (homogenous) for (6 MeV), field size (10x10) cm<sup>2</sup>.

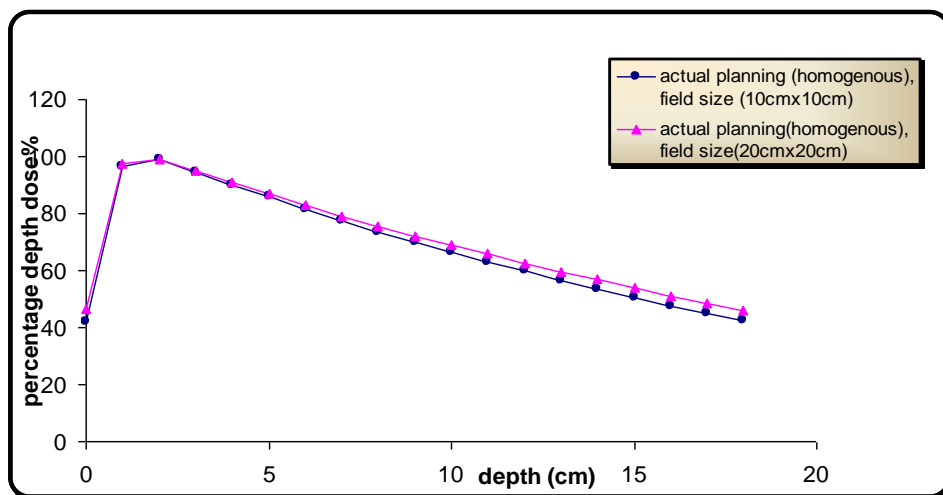


Fig. 3: The change of depth dose % with different depths of water phantom and actual planning (homogenous) for (6 MeV), field size (20x20) cm<sup>2</sup>.

**Discussion**

There are three basic forms of the x-ray or photon interacting with mediums. The first one called photoelectric effect, which the photon energy is generally lower than 200 keV. The second one is Compton effects, which the photon energy is about 0.2 - 5.0 MeV, and the last one named pair production, which the photon energy is larger than 5.0 MeV. In high energy the photoelectric effect disappear. Therefore, the mass attenuation coefficients of three types

of human tissue are proportional to the atomic number  $Z$  and the photon energy  $h\nu$  and result in increasing bone absorption [10].

In higher energy Compton interaction increases, compared to photoelectric absorption. The probability of Compton interaction also depends on the electron density (number of electrons/g  $\times$  density), with the exception of hydrogen, the total number of electrons/g is fairly constant in tissue, thus, the probability of Compton scattering per unit mass is

nearly independent of  $Z$ , and the probability of Compton scattering per unit volume is approximately proportional to the density of the material. Compared to other elements, the absence of neutrons in the hydrogen atom results in an approximate doubling of electron density. Thus, hydrogenous materials have a higher probability of Compton scattering than anhydrogenous material of equal mass. The pair production interaction threshold, it is still unimportant as it needs higher nuclear charge which need higher atomic number and because the human tissue has low atomic number in general pair production is not important only at high energy about 30 MeV photons [11].

When radiation beam enters in medium attenuation takes place and percentage depth dose varies with depth due to the attenuation. Depth dose for the photon is shown in Figs. 2 and 3, which show the relation between percentage depth dose and depth in the medium. One important thing is that the maximum dose is not at the surface but at some depths. This is because of the range of the secondary electron. The electrons that are excited at the surface, on average, will travel a distance before they deposit dose [12].

Table 2 shows the increasing in the field size, the percentage of surface dose increases that this could be caused by an increase of the amount of backscattering in the larger fields [13]. The PDD decreases with depth due to decreased in the phantom energy fluence, as the field size increased, the contribution of the scattered radiation to the absorbed dose increase. This increase in scattered doses is greater at larger depths than at the depth of reference depth,  $d_{max}$ . So the PDD increases with increasing field size [14].

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