A DOSE CONVERSION FACTOR FOR ANY FIELD SIZE BY USING A LOCALLY FABRICATED WATER PHANTOM

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Abstract: Present day practices in radiation therapy require high dose of radiation to be delivered with maximum possible accuracy (±5% or less). Calibration of a radiation beam used for the treatment of cancer patients is based on rather complicated measurements and application of several conversion and correction factors [1,2]. The clinical dosimetry is normally performed by the standard calibrated dosimeter and IAEA standard water phantom. But as the IAEA standard water phantom is very expensive and not available in our country, a locally fabricated water phantom is used to determine a dose conversion factor for measuring the dose at any depth for any field size with same SSD. To get IAEA standard dose a conversion factor of 1.0343 is established. The requirement of this factor may be due to the different properties of the tank material (perspex).

1. INTRODUCTION

Measurements of radiation dose in tissue-like phantom materials are often required to simulate and verify dose delivery to radiation therapy patients. A CIRUS cobalt teletherapy unit (Cis-Bio International, France) of activity 351.5 TBq (01 April 2001) has been installed at the Delta Medical Centre Limited, Dhaka, Bangladesh in November 2001[3]. The success of radiotherapy treatment depends upon the accuracy of radiation dose to be delivered to the tumour volume. Radiation dose requires dose optimisation to the tumour, as it should be within ±5 % or less of the prescribed dose. It is generally assumed that a difference of ±5 % in the delivered dose compared to the prescribed dose to a radiotherapy patient does make a clinically detectable difference in treatment outcome. The establishment of tumour-cure probabilities, optimised time-dose schedules and radiobiological efficiencies require that the systematic uncertainties in dosimetry be made considerably smaller than the uncertainties in estimating tumour volume and response [4].

It may be mentioned that for an individual patient even small differences in dose can make a difference for the treatment outcome. This, however, cannot be clinically demonstrated due to intermittent variability. Dose optimization depends on pre-commissioning test parameters, such as, field size, source to surface distance (SSD), consistency of output dose, percentage depth dose, tissue maximum ratio, wedge, output dose, etc. [5]. It is so important that the dosimetry is the essential component of the total uncertainty in the dose delivery system. Generally the therapy centers measure the output dose in solid phantom by using the ion chamber and electrometer duly calibrated by the Secondary Standard Laboratory, since the absorbed dose cannot be measured directly in human body. Water is recommended as the reference medium for absorbed-dose measurements both for photon and electron beam. Plastic phantoms in slab form such as polystyrene, acrylics and "solid water" may be used as solid phantom but always the dose determination must be referred to water. Physicists perform the systematic approach to the dosimetry of high-energy photons and electrons [6,7] by using the codes, protocols and reports published by the international organizations.

There are a number of factors that relate an instrument reading to an absorbed dose. In IAEA standard water phantom materials are developed by measuring the water equivalent characteristic. So the interaction of radiation with water produces perturbations, which are not similar to that in a locally fabricated water phantom. Because the difference of elementary properties of phantom material, a standard conversion factor is developed to measure the dose at any depth for any field sizes with the same SSD.

2. MATERIALS & METHODS

These tests were performed following the protocol of International Atomic Energy Agency (IAEA). The performance tests of teletherapy unit has been qualified up to internationally certified level. Dosimetry was performed by using calibrated ion chamber (PTW UNIDOS, Serial No. 23323-3713, Vol. 0.3 cc) coupled with the electrometer (PTW UNIDOS, Serial No. 10005-50146) by the PTB Braunsesch weig., Germany. The nominal useful energy range 30 keV – 50 MeV was used for the absolute dosimetry of the teletherapy unit [3]. The experimental set-up for dosimetry procedure is illustrated in Fig.1. The output dose of the ^{60}Co teletherapy unit at source to surface distance (SSD) and source to axis distance (SAD) was measured by using IAEA protocol TRS277[2].

A multi-purpose, water filled phantom was developed for these measurement in radiotherapy treatment. The phantom accommodates common designs of thimble ionization chamber, and both the chamber position and orientation are adjustable. The water phantom of dimensions 45 cm × 45 cm × 33 cm has been fabricated by using the perspex sheets of thickness 1.5 cm. Five pieces of perspex sheets have been used of which three pieces were 45 cm × 45 cm and two pieces were 45 cm × 30 cm in size. Perspex sheets were joined using chloroform.

The entrance window of size 10 cm × 10 cm and thickness 0.5 cm has been made in one wall (45 cm × 45 cm) of the phantom, which does not deform the phantom when filled with water. The entrance window has been grooved at the geometrical center of the wall. This window has been made for the reduction of interaction of radiation with perspex.

In order to protect the ion chamber from the contact of water, a cylindrical ion chamber holder has been made with perspex. The inner and outer diameters of the holder are 0.8 cm and 1.4 cm respectively. The outer diameter of the holder at chamber position was 1.2 cm. To measure dose at various calibration depths, two perspex slabs (3 cm × 30 cm) having 12 holes at distances 2.5 cm, 5.0 cm, 7.5 cm, 10.0 cm, 12.5 cm, 15.0 cm, 17.5 cm, 20.0 cm, 22.5 cm, 25.0 cm, 27.5 cm, 30.0 cm from one end have been used. These slabs have been fixed at the geometrical center of the phantom.

The specifications of the water phantom are: outer length: 45 cm, width: 33 cm, height: 45 cm; inner length: 42 cm, width: 30 cm, height: 43.5 cm; tank material: 1.5 cm thick perspex of density 1.147 gm/cm^3; tank volume: 55 liters. The water phantom is designed for calibration measurements in radiotherapy using horizontal beam.

Doses for the field sizes 4×4, 5×5, 6×6, 7×7, 8×8, 9×9, 10×10, 12×12, 14×14, 16×16, 20×20, 25×25, and 30×30 cm^2 at 5.0 cm depth were measured by using both the locally fabricated phantom as well as the IAEA standard phantom. The doses at 12 calibration depths for the field size 10×10 cm^2 were also measured. During the measurement of doses the middle of the chamber was kept at geometrical center of the fields size, which is shown in Fig. 1.

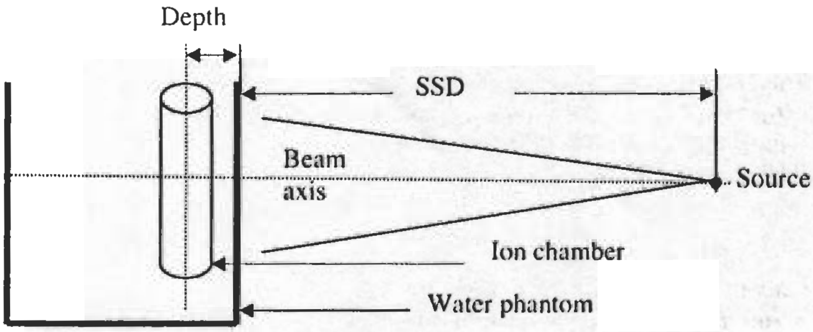

Fig. 1. The phantom configuration used for the experimental dose measurements

3. RESULTS & DISCUSSION

To get IAEA standard dose a factor (conversion factor) has been used. This factor is the ratio of central axis depth dose in IAEA standard phantom to the central axis depth dose in the fabricated water phantom. The value of the factor is shown in Table 1. A standard conversion factor is, thus developed to measure the central axis dose at any point for any field sizes with the same SSD.

$$[\text{Dose in IAEA standard phantom}] = 1.0343 \times [\text{Dose in fabricated phantom}]$$

Table 1. Comparison of IAEA standard phantom doses and fabricated phantom doses

Field size in cm^2	Measured dose in cGy/min	IAEA standard phantom dose in cGy/min	Conversion factor	Actual dose in fabricated phantom in cGy/min	% of dose deviation
4x4	65.01	67.19	1.0343 ± 0.0038	67.24	-0.07
5x5	67.24	69.18		69.55	-0.53
6x6	68.73	71.26		71.09	0.24
7x7	70.56	73.07		72.98	0.12
8x8	71.95	74.63		74.42	0.28
9x9	73.19	75.91		75.70	0.28
10x10	74.53	77.32		77.09	0.30
12x12	76.86	79.62		79.50	0.16
14x14	78.74	81.63		81.44	0.23
16x16	80.48	83.28		83.24	0.05
18x18	81.87	84.86		84.68	0.21
20x20	83.35	86.28		86.21	0.08
25x25	85.83	88.36		88.77	-0.47
30x30	87.32	89.51		90.32	-0.90

In IAEA standard phantom water equivalent material has been used. But the tank material of the fabricated phantom was procured from local market, so its density may not be same as that of the IAEA standard phantom. The density of the used perspex sheets was measured. It was ~1.147 gm/cm^3 whereas the density of IAEA standard phantom material is almost same as that of water. So the interactions of radiation with phantom materials are not same. For that reason the loss of incident beam energy was greater in fabricated phantom than that of IAEA standard phantom. It is shown in Table 1 that the initial measured doses are less than that of IAEA standard phantom. Because of the difference of elementary properties of phantom material this conversion factor is required.

The requirement of the conversion factor may also be due to different wall correction factor for ion chamber holders. The wall correction factor depends on beam energy, wall thickness, wall composition etc. [1,2]. The chamber holders, which were used for the dose measurement in the fabricated phantom and IAEA standard phantom, were not same.

The necessity of that conversion factor may also be due to different scattering properties and attenuation properties of phantom material. The dose at a point in a medium may be analyzed into primary and scattered components [1]. The primary dose is contributed by the initial or original photons emitted from the source and the scattered dose is the result of scattered photons. The scattered dose can be further analyzed into collimator and phantom components, since two can be varied independently by blocking.

The above analysis presents one practical difficulty, namely, the determination of primary dose in a phantom, which excludes both the collimator and phantom scatter. However for mega voltage photon beams, it is reasonably accurate to consider collimator scatter as a part of the primary beam which is called effective primary dose [1]. This effective primary dose is constant for a particular condition of a machine. Due to variation of phantom scattering [8-10] and attenuation of radiation within perspex, the initial measured doses in fabricated phantom were not same as that of IAEA standard phantom doses. The measured dose in locally fabricated phantom does not become same as that of IAEA standard phantom until multiplied by that conversion factor. The percent of error was less than 1% after conversion of the measured doses that is shown in Table 1. So the fabricated phantom may be used for dosimetry studies.

The variation of doses with depths of IAEA standard phantom and fabricated phantom are shown in Fig. 2. The IAEA phantom doses were less than that of fabricated phantom for field sizes above 20×20 cm^2. This may be due to size of the IAEA standard phantom, because according to the protocol; phantom size should be 5.0 cm larger than the field size [1,2,11]. So the measured doses were same up to field size 20×20 cm^2; after that the doses varied slightly.

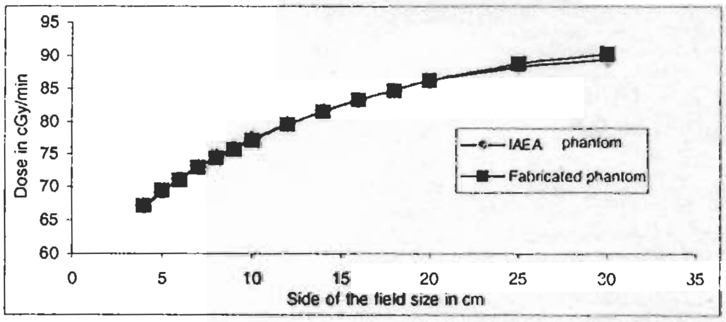

Fig. 2. Variation of dose with side of the field size

Fig. 3 shows the variation of $\log_e$ of central axis dose, as a function of depth. The curve is straight line and the value of coefficient of determination is R^2=0.9991. This curve shows good agreement with standard curves.

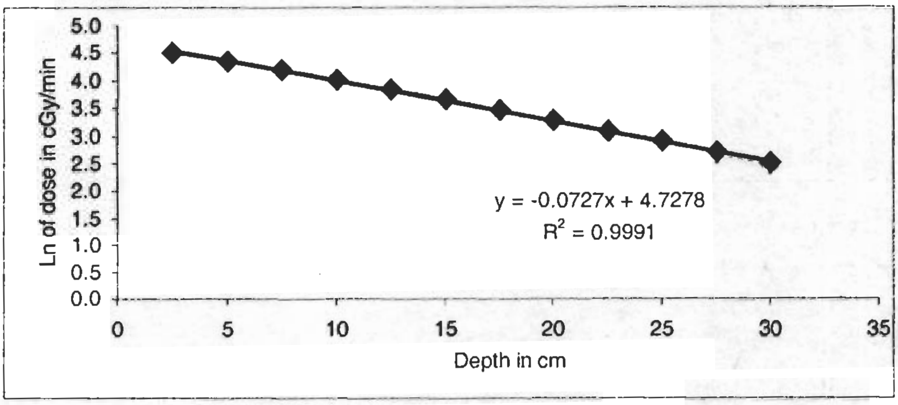

Fig. 3. Depth dose graph for 10x10 cm^2 field size

4. CONCLUSION

The research area is immensely relevant to Bangladesh because of non-availability of water phantom of dimensions 45 cm × 45 cm × 33 cm. Most of the phantoms that are imported are of dimensions 30 cm × 30 cm × 30 cm. The imported phantoms can be used for the measurement of dose up to field size 20 cm × 20 cm. But the fabricated phantom can be used for the measurement of dose up to field size 35×35 cm^2. In a few treatments (lung, total body irradiation) and for machine commissioning large field sizes are required. The use of ionising radiation for treatment of cancer in Bangladesh is growing. The phantoms used in the private and government hospitals or clinics, are imported. If water phantom can be fabricated in the country and used for the accurate calculation of the radiation dose in cancer therapy, it will reduce the dependence on imported phantoms. This will result in saving of foreign currency. Also people will have enough confidence in locally available radiation dosimetry.

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