DOSIMETRIC COMPARISION FOR RADIATION QUALITY IN HIGH ENERGY PHOTON BEAMS

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The beam quality Q of high energy photon beams produced by a clinical linear accelerator was assessed using the IAEA TRS-398, AAPM's TG-51 and DIN 6800-2 international protocols. The tissue phantom ratio $TPR_{20,10}$ is the beam quality Q of high energy photons produced by clinical accelerators and is measured at 10 g cm^{-2} and 20 g cm^{-2} depth in a water phantom with a constant source - phantom surface distance (SSD) of 100 cm and a field size of 10 cm x 10 cm at the plane of the chamber. According to AAPM's TG-51 the specified beam quality $\%dd(10)_x$ is the percentage depth dose at 10 g cm^{-2} in a water phantom due only to photons.

Key words: high energy photons, radiation therapy, tissue phantom ratio, clinical dosimetry.

1. INTRODUCTION

The determination of absorbed dose delivered to a patient during radiotherapy treatment, is based on the measurement of absorbed dose to water [1]. The quality of a photon radiation beam is a basic quantity used to enable the commissioning of radiotherapy installations that generate photon beams, and is used in calculating the patient's received radiation dose. Also, in radiotherapy it is most usefully expressed in terms of its penetrating power which is mainly a function of the mean photon energy and may be fully described by its depth dose characteristics in water [2, 3].

The quality of a photon radiation beam based on the tissue-phantom ratio, $TPR_{20,10}$ in IAEA TRS-398 Code of Practice and DIN 6800-2. In the AAPM's TG-51 the quality of photon radiation is specified by the percentage depth dose at 10 g cm^{-2} in a water phantom, % $dd(10)_x$. Plane-parallel chambers can also be used to determine beam quality but were not used in this paper [4-8].

The tissue-phantom ratio is obtained from the ratio of the absorbed doses on the central axis at depths of 20 g cm^{-2} and 10 g cm^{-2} in a water phantom or by measurement of the percentage depth dose (PDD) at depths of 20 g cm^{-2} and 10 g cm^{-2}. After measuring, the PDD is useful firstly in radiotherapy treatment and secondly to evaluate and investigate the physics of radiation beams as function of field size, photon energy and source - surface phantom distance, SSD. Also, the measurement of absorbed dose is performed using cylindrical ionization chambers and using water or any other equivalent media phantom, which is kept perpendicular on the path of beam [4-8].

The measurements for determination of the photon beam quality were carried out at the Mevatron Primus clinical accelerator belonging to the Department of Radiation Oncology at the "Coltea" Clinical Hospital, Bucharest, Romania, at a constant source-phantom surface distance of 100 cm and a field size of 10 cm x 10 cm at the phantom surface [4]. For a better assessment of the obtained results and for demonstrating a good traceability of the measurements the z-score was calculated [1, 9].

2. EQUIPMENT AND METHOD

For determining the radiation quality of the photon beam at a Mevatron Primus clinical accelerator, a PTW MP3-M water phantom (PTW, Freiburg, Germany) with a scanning range of 50 cm x 50 cm x 40.75 cm was used. The percentage of absorbed dose was determined along the central axis at a source - phantom surface distance (SSD) of 100 cm, using two Semiflex chambers (Type TN 31010, PTW, Freiburg, Germany) with an active volume of 0.125 cc. For better precision, an ionization chamber was connected to the T10005 UNIDOS electrometer while the other was connected to the acquisition system of the Mevatron Primus clinical accelerator.

The Mevatron Primus clinical accelerator that belongs to the Department of Radiation Oncology of the "Coltea" Clinical Hospital, Bucharest, Romania is manufactured by Siemens Medical Systems Inc-Oncology Care Group, Germany. This accelerator supplies electron beams and photon beams and has an adjustable field size [8]. The measurements presented in this paper were performed in a 6 MV high energy photon beam, with a field size of 10 cm x 10 cm.

The dosimetric equipment that was used for the measurements belongs to Department of Radiation Oncology of the "Coltea" Clinical Hospital and to the Secondary Standard Dosimetry Laboratory at High Energies (STARDOOR) [10].

For the purposes of reference beam dosimetry, the beam quality in accelerator photon beams in IAEA TRS-398 and DIN 6800-2 is specified by the tissue-phantom ratio, $TPR_{20,10}$ and in AAPM's TG-51 the beam quality is specified by the percentage depth dose at 10 g cm^{-2} in a water phantom, $\% \, dd(10)_x$. Both are specific for high-energy photons produced by clinical accelerators with a beam quality Q but $\%dd(10)_x$ does not include the effects of electron beam contamination

[4-8]. These are the basic procedures used to commission radiotherapy photon beams, and therefore are used in calculating the patient's radiation dose [2].

The method used for determining the $TPR_{20,10}$ constitutes in measuring absorbed dose and percentage depth dose at 10 g cm^{-2} and 20 g cm^{-2} in water phantom [4, 5, 8]. The quality of the photon beam was determined by utilizing an irradiation geometry that kept constant the source-phantom surface distance at 100 cm and a 10 cm x 10 cm field size at the phantom surface and at the chamber plane [4, 5, 10-12].

The ionization chamber TN 31010 was calibrated with ^{60}Co source and hence the chamber carried a calibration factor $N_{D,w}$. Absorbed dose to water was determinate in according to the IAEA TRS-398, AAPM's TG-51 and DIN 6800-2 international protocols [4-7].

Table 1

Formula used for the determination of absorbed dose to water

IAEA TRS-398	AAPM's TG-51	DIN 6800-2
$D_{w,Q} = N_{D,w,Q_0} \cdot M_Q \cdot k_{Q,Q_0}$	$D_{w,Q} = N_{D,w}^{Co-60} \cdot M \cdot k_Q$	$D_{w,Q} = (M - M_0) \cdot N \cdot \prod_{i=1}^{n} k_i$

In particular, $TPR_{20,10}$ is independent of the distance from the source and is determinate with the formulae [4, 5]:

$$TPR_{20,10} = 1.2661 \cdot PDD_{20,10} - 0.0595 \qquad (1)$$

and

$$TPR_{20,10} = 1.2661 \cdot D_{20} / D_{10} - 0.0595 \qquad (2)$$

where $PDD_{20,10}/(D_{20}/D_{10})$ is the ratio of the percentage depth dose/absorbed dose at 20 g cm^{-2} and 10 g cm^{-2} depths for a field size of 10 cm x 10 cm at an SSD of 100 cm [4, 5].

The method used for determining the $\%dd(10)_x$ constitutes in determining the percentage depth at 10 g cm^{-2} depth in a water phantom and is defined for a field size of 10 cm x 10 cm at the source-phantom surface distance of 100 cm. For low-energy beams, i.e., for energies below 10 MV with $\%dd(10) \leq 75\%$ is calculated using the formula:

$$\%dd(10)_x = \%dd(10) \qquad (3)$$

where the value of $\%dd(10)$ is the measured photon beam percentage depth dose at 10 g cm^{-2} depth in a 10 cm x 10 cm field on the surface of a water phantom at an SSD of 100 cm [6, 7].

3. EXPERIMENTAL SET-UP

The gantry was set to upright position and the water tank is set for a constant SSD of 100 cm. The field size was 10 cm x 10 cm at the surface of the water phantom. The distance and field sizes were measured using a laser system. All distances and field sizes were measured rigorously. The ionization chamber was positioned using a detector positioning system at the effective point of measurement. In the photon beam the PDD data was measured along the central axis at a constant SSD of 100 cm and a10 cm x 10 cm square field size [8, 12] and the ionization chamber was moved to different depths [11]. The measurements were performed at 6 MV energy.

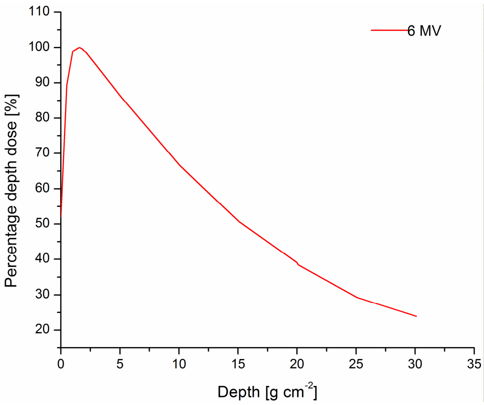
In order to measure and compare the results, the percentage depth dose was firstly measured using the Semiflex ionization chamber belonging to the STARDOOR Laboratory and then it was measured using the Semiflex ionization chamber belonging to the "Coltea" Hospital. The ionization chamber belonging to the STARDOOR laboratory was connected to the UNIDOS dosimeter and the ionization chamber belonging to the "Coltea" Hospital was connected to the Mevatron Primus accelerator acquisition system. The percentage depth dose was calculated by using the ionization chamber belonging to the STARDOOR laboratory to determine the absorbed dose in water for each point of measurement. The acquisition system of the Mevatron linear accelerator was used to measure the PDD directly [8].

For determining the radiation quality of the photon beam for this experimental set-up, according to IAEA TRS-398 and DIN 6800-2, we will consider the ratio of depth doses on the central axis at 20 g cm^{-2} and 10 g cm^{-2} depths, respectively D_{20}/D_{10} [4, 5]. The results of the measurements according to IAEA TRS-398 and DIN 6800-2 are equivalent. In according to AAPM's TG-51 only the percentage depth dose at 10 g cm^{-2} will be considered. To avoid experimental and stability errors the quality of the radiation beam was measured in six irradiation stages for the three international protocols.

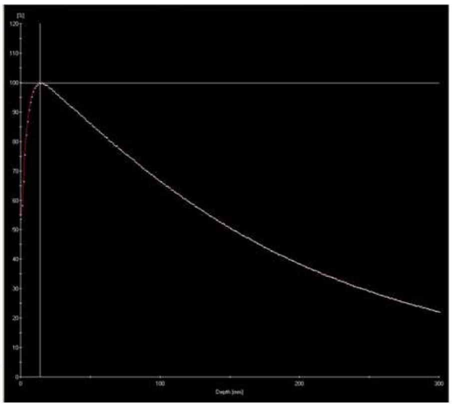
The pressure and temperature were monitored and recorded for each measurement. Correction for leakage and ion-recombination effect was applied and the uncertainty for measuring absorbed dose to water was calculated in conformity with reference standards.

4. RESULTS AND DISCUSSION

The percentage depth dose measured with the two ionization chambers is presented in Fig.1. From the figures we can observe that the percentage depth dose measured with both ionization chambers is almost identical [12]. After determining the PDD, the quality of the radiation beam was calculated using the relationships 1 and 3. The determination of correction factors was performed according to each standard [4-6].



a)



b)

Fig. 1 - The percentage depth dose: a) determined using the ionization chamber of the STARDOOR Laboratory; b) determined using the acquisition system of the "Coltea" Hospital

The results of quality of radiation photon beam measured in six irradiation stages for the three international protocols are presented in Table 2 along with the specific correction factors for the beam radiation quality that were deduced for each IAEA TRS-398, AAPM's TG-51 and DIN 6800-2 protocols. The corresponding value was then interpolated for our ionization chamber TN 31010 [7]. Uncertainty for the measurements was calculated in conformity with the specified standards. These values are in the limit of uncertainty given by the manufacturer.

Table 2

Photon beam radiation quality obtained at 6 MV at the Mevatron Primus clinical linear accelerator using the three international protocols (IAEA TRS-398, AAPM's TG-51 and DIN 6800-2)

Photon energy	IAEA TRS-398		AAPM's TG-51		DIN 6800-2	
	$TPR_{20,10}$	$k_{Q,Qo}$	$\%dd(10)_x$	k_Q	$TPR_{20,10}$	k_Q
6 MV	0.673	0.991	67.20	0.990	0.673	0.989
6 MV	0.673	0.991	67.41	0.990	0.673	0.989
6 MV	0.670	0.991	67.29	0.990	0.670	0.989
6 MV	0.673	0.991	66.37	0.992	0.673	0.989
6 MV	0.673	0.991	66.82	0.991	0.673	0.989
6 MV	0.672	0.991	67.49	0.990	0.672	0.989

Assessing the photon beam radiation quality was made using the z-score, determined according to the International Standard ISO 13528 [9]. The values of the z score are presented in Fig. 2 and in Table 3 and are within the range [-2, +2] which proves that the quality system implemented in the STARDOOR laboratory (written procedures, trained personnel, etc.) ensure a high quality level of its services.

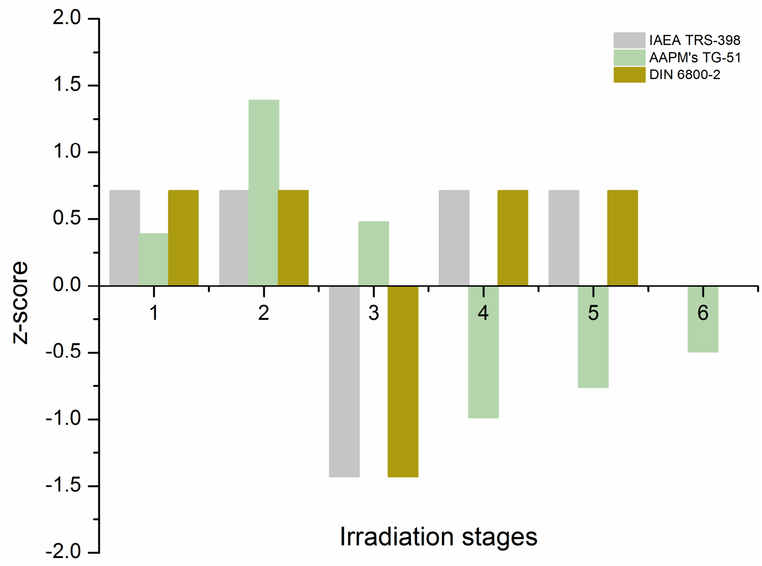


Fig. 2 - z-score for measurement results at 6 MV photon beam for the quality of radiation photon beam

Table 3

z-score for measurement results at 6 MV photon beam for quality photon beam

Photon energy	IAEA TRS-398		AAPM's TG-51		DIN 6800-2	
	$TPR_{20,10}$	z-score	$\%dd(10)_x$	z-score	$TPR_{20,10}$	z-score
6 MV	0.673	0.71	67.20	0.39	0.673	0.71
6 MV	0.673	0.71	67.41	1.39	0.673	0.71
6 MV	0.670	-1.43	67.29	0.48	0.670	-1.43
6 MV	0.673	0.71	66.37	-0.99	0.673	0.71
6 MV	0.673	0.71	66.82	-0.76	0.673	0.71
6 MV	0.672	0.00	67.49	-0.49	0.672	0.00

To compare the result of absorbed dose to water obtained in conformity with the three protocols, the absorbed dose to water was measured at reference depth, $z_{ref} = 5$ g cm^{-2}. IAEA TRS-398 has been taken as reference. The ratio of absorbed dose to water was obtained by dividing the doses of the protocols by the doses of dosimetry protocol IAEA TRS-398. The results presented in Fig. 3 show that the absorbed dose to water at 5 g cm^{-2} reference depth obtained following the three protocols are close to each other. Also, Fig. 3 shows that the AAPM's TG-51 yielded approximately the same value as IAEA TRS-398 whereas DIN 6800-2 gave a minor deviation from the IAEA's protocol. The discrepancies are within acceptable range. The maximum dose ratio discrepancy when referencing AAPM's TG-51 and DIN 6800-2 protocols to the IAEA TRS 398 is between -0.001% to +0.18% [7].

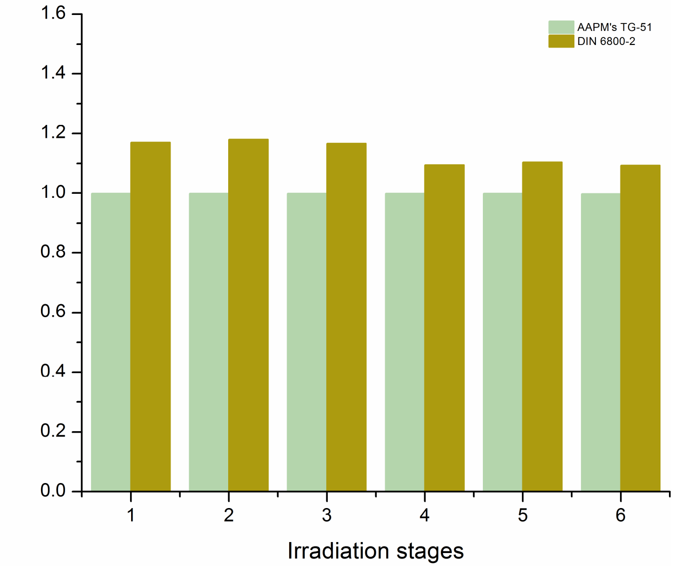


Fig. 3 - Comparison of the discrepancy between absorbed dose ratios

5. CONCLUSION

In this article, the measurements for determining the quality of a 6 MV photon radiation beam energy beam have been performed at the Mevatron Primus clinical accelerator of the "Coltea" Clinical Hospital, Department of Radiation Oncology, Bucharest, Romania. The radiation quality was determined following the international protocols: IAEA TRS-398, AAPM's TG-51 and DIN 6800-2. According to IAEA TRS-398 and DIN 6800-2, the photon beam radiation quality refers to the tissue-phantom ratio, $TPR_{20,10}$ and in AAPM's TG-51 it is given in terms of percentage depth dose at 10g cm^{-2} in water phantom, $\%dd(10)_x$ [4-6].

The photon radiation beam for 6 MV energy obtained with the IAEA TRS-398 and DIN 6800-2 international protocols are similar, whereas the other measured with the AAPM's 6800-2 protocol is slightly different because the method is different [7]. To show if the values obtained for the radiation quality are in accordance with the manufacturer's date the z score was calculated. The results obtained are within the range [-2; +2] which shows that the values obtained for the radiation quality with the three standards are within the range of the manufacturer's measuring range.

Absorbed dose to water values, measured at a reference depth of 5 g cm^{-2}, following the three protocols are similar. To compare the result of absorbed dose to water the IAEA TRS-398 protocol has been taken as reference. The AAPM's TG-51 protocol yielded approximately the same value as IAEA TRS-398 whereas DIN 6800-2 gave a minor deviation from the IAEA's protocol. Despite the discrepancies the values are within acceptable range. The maximum dose ratio difference between the AAPM TG-51 and DIN 6800-2 protocol with reference to the IAEA TRS-398 is from -0.001% to +0.18%. This comes to demonstrate that the quality system implemented in the STARDOOR laboratory (written procedures, trained personnel, etc.) assures a high level of service quality.

Acknowledgements: Work supported by the National Authority for Scientific Research and Innovation, Romania (Nucleus Program PN 0939/0105).

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