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The Dosimetric Comparison between Measured Tissue Maximum Ratio Directly by Water Phantom and That Calculated from Percentage Depth Dose Measurments in Small Field and Determind the Differnces between Two Methods

Ehab Marouf Attalla [1, 2], Shaimaa Shoer[1], Rasha A. Elawady[2,*]

1. Physics Unit-Radiation Oncology, Children's Cancer Hospital, Cairo, Egypt
2. Department of Radiotherapy & Nuclear Medicine, National Cancer Institute, Cairo University, Cairo, Egypt

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ABSTRACT

Introduction: The aim is to observe that the measurement of tissue maximum ratio (TMR) by water phantom directly differs from the calculation of TMR from percentage depth dose (PDD) or not.
Material and Methods: The linear accelerator Siemens (6 MV & 10MV) with 82 leaves (MLC)-based stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT). The water phantom (PTW) was used for measuring the dosimetric parameter of TMR &%DD. This data was calculated using 0.125 cc simeflex ionization chamber. The small fields have different sizes ranging from 12.50 to 40.00 mm in diameter.
Results: There were small observations of mean error ≤ 1.50 % for all collecting data related to depths and field sizes. The Statistical Package of Social Science (SPSS) (version 26) to generate results. Wilcoxon Signed Ranks Test was used to compare two groups; (p ≤ 0.05) was considered significant. There were no significant differences between TMR data. The measured TMR data calculated from %DD had a strong positive correlation for cone sizes from 1.0 cm x1.0 cm to 10.0 cm x10.0cm.
Conclusion: It has been shown that the calculation of TMR data from PDD agrees with the measuring values directly, and it is accepted for use in treatment.

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Introduction

The physical dosimetric parameter such as percentage depth dose (PDD) or tissue maximum ratio (TMR) can be used for monitor unit (MU) calculation [1]. This parameter can measure experimentally. It is easy to measure PDD directly by using a water phantom than TMR. The ion chamber moves up and down on the central axis of field size with a fixed source to surface distance SSD = 100 cm. This option present in an all automatic water phantom, but for TMR, it needs to drain water continuously during measurements. The ionization chamber present at a fixed distance from the source (source axis distance SAD= 100). It requires extra fees for obtaining this option [2].

The accuracy required for stereotaxy is the same as standard radiation therapy for which the International Commission on Radiation Units and Measurements (ICRU) recommended that dose delivery to a patient has accuracy with ±5.0%, based on dose-response analysis data and errors evaluation in delivery of dose [3]. Because of this reason, TMR values can calculate from PDD curves. This calculation can represent an option on a water phantom program. Several authors explain the conversion method of TMR values from PDD data [4–6]. The phantom scatter factor should measure when TMR is calculated from %DD data and presented in the literature [7,8]. These tables of phantom scatter factors for field sizes more than 4.0 cm2 for the energy of 6-MV are mentioned in the literature [9].

The cone sizes are less than the material volume of build-up, the measured factor of collimator scatter is imprecise. Because there are no lateral electron equilibrium presents [10]. To avoid this problem, the phantom scatter factor should be measured. Some authors used low-density material to determine the phantom scatter factor [11- 15]. In small cone sizes presented in stereotaxy, the calculated TMR value from PDD is not applicable because of the requirement of measuring the phantom scatter factor. PDD should measure for field size less than the smallest cones. L.J. van Battum et al [12] describe the calculation of TMR values from PDDs measurements

*Corresponding Author: Tel: 01113534945; Email: rasha.elawady@nci.cu.edu.eg

for all cone sizes, and total scatter factors at a depth of maximum dose (15.0 mm for the energy of 6 MV).

This paper will describe the differences between direct TMR measurements from water phantom and TMR calculated from simple PDD measurements and total scatter factors. This measurement will represent all available cone sizes at a depth of maximum dose for energy 6 MV. Via these differences, we can judge if there is a need to purchase a water phantom with a water pump to drain water continuously during TMR measurements or not.

Materials and Methods

The stereotactic radiosurgery unit based on the XKnifeRT2 treatment-planning system (TPS) from RADIONICS© (Burlington, MA, Massachusetts, United States) has been installed in Children's Cancer Hospital on Siemens 6 MV linear accelerator. The collimator of SRS/SRT is placed on the faceplate of the collimator at ONCOR M6/6ST. The tertiary collimator contains the actual cones (10.0 cm long). These cones are about 12 circular shapes ranging from 12.5 to 40 mm in diameter with 2.5 mm increment. The 3D Radionics treatment planning system that utilizes the Xknife RT2 dose algorithm is used for treatment planning.

3D water phantom (PTW-MP3-M-from the dosimetry company of PTW-Freiburg) is used for measuring PDD, and TMR. The Water phantom has a range of scanning 50 cm × 50 cm × 40 cm. Semiflex ionization chamber PTW (31010) from the dosimetry company of PTW-Freiburg of 0.125cc was used for collecting measurements [16-18]. The measurements take along the central axis of field sizes. PDD values were taken using the ion chamber moving along the central axis of field size with fixed source surface distance (from source to water phantom surface) SSD = 100 cm. TMR was measured by draining water throw phantom during measurements. The ionization chamber is present at a fixed distance from the source to chamber distance (source chamber distance SCD= 100). PDD and TMR measured up to 22 cm in depth along the central axis. PTW- MEPHYSTO mcc software version 1.5 is used for the analysis of the data. A comparison between the measured TMR and calculated value from PDD was performed using a 2-tailed paired Student's T-test with a p-value < 0.05. The comparisons between two dose volume histogram (DVH) of the two different calculation methods for the same patient are performed.

The TMR of a certain field size r_d at depth d is calculated from PDD by equation (1) using BEAMSCAN and analysis_Software_version 4 (TPR/TMR and OCR table generator) [16]:

$$\mathrm{TMR}(r_d\,, d) = \frac{PDD(r_{s,}\ d{,}SSD)}{100}\left(\frac{100+d}{100+d_{max}}\right)^2\left(\frac{S_p(r_{d_{max}})}{S_{p(r_d)}}\right) \qquad (4)$$

Where,

r_d → is the field size at the depth d.

r_s → is the field size projected at water phantom surface.

Sp ($r_{d_{max}}$) → is the phantom scatter factor of field size $r_{d_{max}}$ is defined from equation (2) as:

$$S_p\left(r_{d_{max}}\right) = \frac{S_{c,p}\ (r_{d_{max}})}{S_c\,(r_d)} \qquad (2)$$

Where, S_c is the collimator scatter factor and $S_{c,p}$ is the output factor.

The field sizes $r_{d_{max}}$ and r_d are related by equation (3) based on geometry:

$$r_{d_{max}} = \frac{(100-d=d_{max})}{100} r_d \qquad (3)$$

Results

A comparison study was performed between the 2 methods - (a) direct measurement of TMR values from water phantom; (b) TMR values calculated from PDD. The parameters that characterize the TMR curve represent in Table 1for the 7 square field sizes. This parameters are:

1- D_{max}.is the depth of dose maximum.
2- TMR at the surface is defined at 0.5mm depth (TMRs).
3- TMR at different depths of 10.0 mm, 20.0 mm, 30.0 mm, 50.0 mm, and 100.0 mm (TMRs TMR 10, TMR 20, TMR 30, TMR 50, and TMR 100, respectively).

A maximum difference between measured TMR and that calculated from PDD at 10 cm depth is 2% noted at cone size 10.0cm x10.0cm and 2.0cm x2.0cm. The other cone sizes don't exceed about 1.50%. For depth 5.0cm the maximum differences don't exceed about 1.0 % except 1.0cm x1.0cm and 2.0cm x2.0cm cone sizes 2.0% and 1.50% respectively. Measured and calculated TMR values along the central axis of a 1.0 cm × 1.0 cm, 2.0 cm × 2.0 cm, and 5.0 cm × 5.0 cm 6MV photon beam are shown in Figures 1, 2, and 3, respectively. The differences at depth 1cm increase from a small cone size to a large one to reach the value of ≤ 3.0%.

The percentage of mean difference in TMR data between the two methods is ranged from 0.40 % to 1.50 % related to the field size dependence. The mean percent difference in the TMR data between two different methods for the 7 square field sizes is present in Table 2 as a mean ± standard deviation. The Statistical Package of Social Science (SPSS) (version 26) is used to generate results. 2-tailed paired Student's T-test was used to compare two groups; (p ≤ 0.05) was considered significant. 2-tailed paired Student's T-test not disclosed statistically significant difference between TMR data of p-value < 0.050. The correlation coefficient between the differences in TMR data with the field size for the 7 square field sizes was tabulated in Table 2.

Table 1. Comparison of values of d_{max}, TMR at the surface (TMRs), at depths of 1 cm, 2cm, 3cm, 5cm and 10 cm for the Measured TMR and TMR calculated from PDD.

field size (cm)	depth(mm)	$D_{max\ (mm)}$	TMRs	TMR10	TMR20	TMR30	TMR50	TMR100
1x1	TMR measured	12.5 mm	54.4	99.7	98.2	94.1	85.4	68
	TMR calculated	18 mm	40.4	97.8	99.1	95.5	87.3	68.7
2x2	TMRm	15mm	52.2	98.1	99.1	95.1	87.1	69.3
	TMRc	16mm	45.2	95.4	99.4	96	88.4	70.8
3x3	TMRm	16.5mm	51.9	97.7	99.4	96	88.5	71.1
	TMRc	18mm	46.5	94.9	99.4	96.2	88.6	71.8
4X4	TMRm	16mm	57.8	97.6	99.4	96.2	89.2	72.2
	TMRc	18mm	46.0	94.6	99.4	96.9	89.6	73.2
5X5	TMRm	14.5mm	61.3	98.1	99.3	96.3	89.8	73.2
	TMRc	18mm	46.4	94.7	99.6	97.1	90.6	74.2
7X7	TMRm	14.5mm	56.7	97.8	99.4	96.8	91.1	75.3
	TMRc	18mm	48.6	94.8	99.9	97.4	92.0	76.4
10X10	TMRm	16mm	58.4	97.9	99.7	97.3	91.9	77.4
	TMRc	18mm	50.3	94.9	99.9	97.7	92.6	79.0

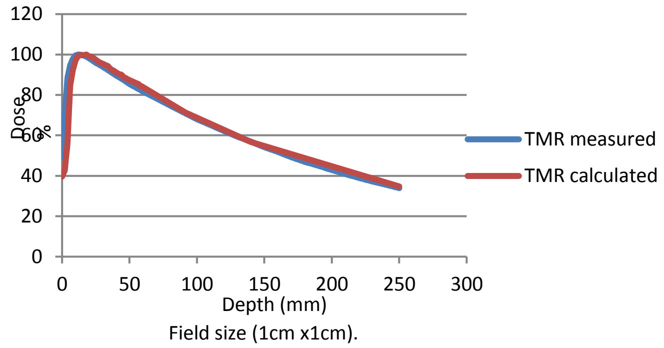


Figure 1. Measured TMR data and TMR values calculated from PDD values along the central axis of a 1 cm × 1 cm, 6MV photon beam.

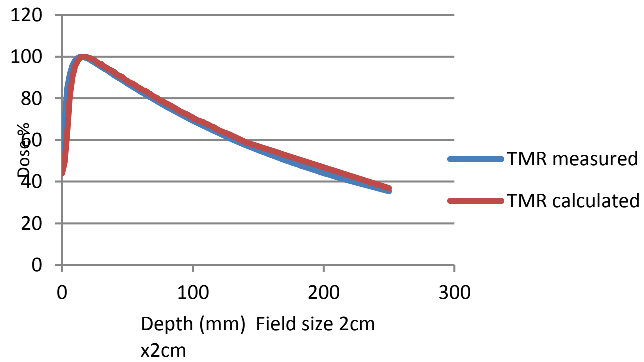


Figure 2. Measured TMR data and TMR values calculated from PDD values along the central axis of a 2 cm × 2 cm, 6MV photon beam

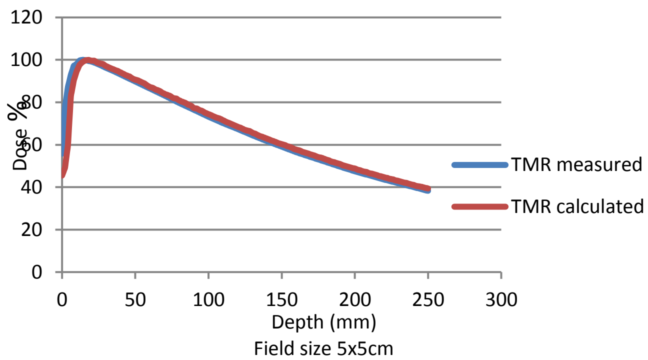
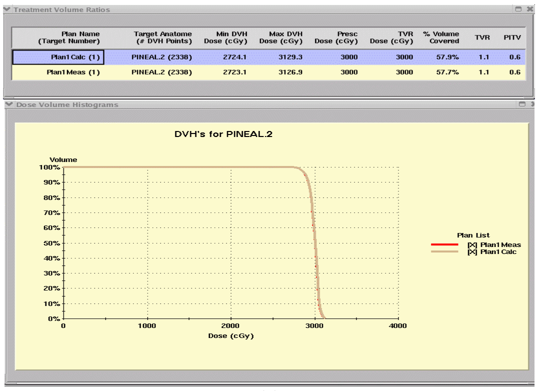


Figure 3. Measured TMR data and TMR values calculated from PDD values along the central axis of a 5 cm × 5 cm, 6MV photon beam.

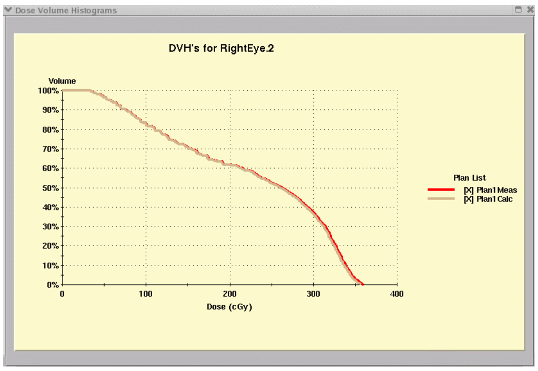
Table 2. Percent difference in the TMR values between two methods represented as mean ± standard deviation, 2-tailed paired Student's T-test(p-value < 0.05), and The correlation coefficient between the difference in TMR values for the 7 square field sizes.

field size (cm)	p-value< 0.05	Correlation coefficient	% Difference
1x1	0.234	R^2=0.911	1.5 ±0.85%
2x2	0.25	R^2=0.947	1.3±0.83%
3x3	0.147	R^2=0.982	0.4±0.66%
4x4	0.165	R^2=0.955	0.6±0.7%
5x5	0.177	R^2=0.916	0.9±0.8%
7x7	0.209	R^2=0.950	0.9±0.76%
10x10	0.199	R^2=0.949	0.9±0.85%

Data from the comparison between the measured TMR and which calculated from PDD in the XKnif planning system were so close in DVH. Figure 4 (a) contains the DVH of the target for both calculation methods. The Match percentage between them for maximum and the minimum dose was about 99.9 %. For risk organs, the differences appear to be very small. The DVH curves are nearly the same in figure 4 (b).



(a)



(b)

Figure 4. (a) the DVH of target for Measured TMR data and TMR values calculated from PDD values. For risk organ (b), the differences appear to be very small.

Discussion

TMR is an essential factor that should feed the treatment planning system to calculate dose distribution and determine the MUs for radiation beams. The interest in these measurements comes from determining the easiest and least expensive way. The aim is to study and evaluate the physical and dosimetric characteristics of the radiation beam for TMR measured and calculated from PDD.

The Data are affected and differ in build-up region because the small cones lack laterals scattering [1]. The variation in this region may also appear due to the uncertainty in water level during their reservoir draining method [20]. The deviation in the depth of maximum dose-related to low photons energy or secondary electrons scattered. These electrons scattered resulted from the scattering in the cone (electron contamination in the beam) [12, 19, 21].

The TMR values calculated from PDD agree with the TMR values measured to be smaller than 2% [12, 20]. The differences between measured TMR and calculated from PDD values are larger than 1.0% for field sizes 1.0 cm x 1.0 cm and 2.0 cm x 2.0 cm but not exceed about 3.0% [20]. The result showed that increasing mean differences with decreasing field size [16, 20, 22]. The mean difference between measured TMR and calculated PDD Values ranges from 0.40 % to 1.50 depending on the field size [20, 23]. The results have a strong positive correlation ranging from % 0.911 % to 0.982% [16]. All tolerances are within the clinically acceptable tolerance limit recommended by IAEA and AAPM. The medical physicist can utilize PDD measurement to calculate TMR, and they don't need software in a water phantom for direct TMR measurement. The calculation of TMR data from PDD using the standard method agrees with the measuring values directly and it is accepted for use in treatment [2, 12, 13, 14, 16, 23].

Conclusion

The calculation of TMR values from PDD data presented a good agreement with directly TMR measurement data from the water phantom. It is suitable for clinical use for all clinically relevant depths and field sizes. The differences between TMR measurement data from the water phantom and that calculated from PDD values show a strong positive correlation with the field sizes ranging from 1.0 cm x1.0 cm to 10.0 cm x10.0 cm. This result will facilitate the dosimetric measurement for medical physicists for the treatment planning system. This is by using the conversion method in water phantom software to calculate TMR values from PDD data. The direct measurement of TMR does not need and can be avoided because this option is expensive and not available for all water phantoms.

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