THE STUDY OF ABSORBED DOSE DETERMINATION IN HIGH ENERGY ELECTRON AND PHOTON BEAMS USING NEW CODE OF PRACTICE IAEA-TRS 398 COMPARED WITH IAEA-TRS 277

Sivalee **SURIYAPEE**,[1] Tassanee **LAYANGKUL**,[2] Surat **VINIJSORN**,[3] Siri **SRIMANOROTH**[4]

ABSTRACT

In Thailand, the Secondary Standard Dosimetry Laboratory (SSDL) provided the calibration factors to the hospitals all over the country for the absorbed dose determination in external beam radiotherapy using IAEA - TRS 277 protocol. The SSDL started the project of using TRS 398 protocol instead of TRS 277 protocol by providing the $N_{D,W}$ factors for the hospitals who participated in the project. Three university hospitals from ten hospitals which participated in this project were selected for analyzing the absorbed dose determined by TRS 398 compared with TRS 277. For photon beams, the measurement were performed in water phantom for 6 and 10 MV x-ray beams and Cobalt-60 gamma beams with NE 2571 0.6 cc thimble chamber. For electron beams, the cross calibration of PTW 23343 Markus chamber with NE 2571 chamber were performed to derive the $N_{D,W}$ factor for the highest electron energy. Then the dose measurement of the highest electron beams were undertaken with Markus chamber in water phantom. The results show the comparable of absorbed dose to water of photon beams determined by both TRS 398 and TRS 277 with the maximum discrepancy of 0.9%. But for electron beams, the maximum discrepancy is high up to 5%. The complicated technique of electron measurement may cause the uncertainty both in the measurement and also in the absorbed dose determination. Before the implementation of the new code of practice, studying and understanding the code of practice is necessary.

INTRODUCTION

The absorbed dose determination in external beam radiotherapy using the calibration factor in term of absorbed dose to water $N_{D,W}$ was introduced by IAEA-TRS 398[1] instead of using the calibration factor based on air kerma, N_K by IAEA-TRS 277.[2] The project of using the new IAEA code of practice TRS 398 in Thailand has started by Division of Medical Device, Secondary Standard Dosimetry Laboratory (SSDL) since 2002. The aim was to introduce the hospital to be familiar and to start using the new protocol before implementation to the clinic. The hospital that participated in this project sent the

[1] Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Chulalongkorn University, Rama IV road, Bangkok, Thailand.

[2] Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Rama VI Road, Bangkok, Thailand.

[3] Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand.

[4] Division of Radiation and Medical Devices, Department of Medical Sciences, Ministry of public Health, Nonthaburi, Thailand.

dosemeter to the SSDL for N_K and $N_{D,W}$ calibration factor. After the calibration factors have been provided, all hospitals were requested to make the measurement for 6 and 10 MV photon beams, Cobalt-60 gamma beams and the highest energy electron beams. The worksheets for absorbed dose determination for each type of beam were also sent to the hospitals. The SSDL gave both TRS 277 and TRS 398 worksheet and the parameters for absorbed dose determination of both protocol were needed to be filled and sent back to SSDL. There were ten hospitals participated in this project. In this study, we analyzed three university hospitals that completed all types of required radiations. The absorbed dose to water at D_{max} based on the absorbed dose to water concept $N_{D,W}$ and the air kerma concept N_K are compared.

MATERIALS AND METHODS

Three hospitals in this study comprise of King Chulalongkorn Memorial hospital, Ramathibodi hospital and Siriraj hospital. Table 1 shows the types of the radiotherapy machines and the beams used for each hospital. Table 2 shows the types of dosemeter system used and the calibration factors for photon beams which supplied by the SSDL. For photon beams, the measurements were performed in water phantom with NE 2571 0.6 cc thimble chamber for field size of 10x10 cm. The TRS 277 recommended the measurement at the effective point which is displaced from the center of the chamber equals to 0.6 cc of the radius of the chamber. While the TRS 398 recommended the measurement at the center of the chamber. The reference depth are 5 cm for 6 MV photon beams and Cobalt-60 beams and 10 cm for 10 MV photon beams. King Chulalongkorn Memorial hospital and Siriraj hospital made the measurements by placing the chamber center at a reference depth, Ramathibodi hospital placed the chamber at the effective point of measurement at a reference depth. The absorbed dose to water at D_{max} for each protocol was calculated by the percentage depth dose at depth which the chamber was placed.

Table 1. Types of the radiotherapy machines and the beams from three university hospitals

Hospital	Machine	Beam
Chula:	Clinac 1800	6, 10 MV X-ray, 20 MeV electrons
	Theratron 80 Elite	Co-60 gamma beams
Rama:	Clinac 2100C	6, 10 MV X-ray, 20 MeV electrons
	Theratron 780C	Co-60 gamma beams
Siriraj:	Clinac 23 EX	6, 10 MV X-ray, 22 MeV electrons
	Theratron 780C	Co-60 gamma beams

Table 2. Types of chambers and dosemeters for photon beam measurements with the calibration factors that supplied by SSDL both in $N_{D,W}$ and N_K and the ratio of $N_{D,W} / N_K$.

Dosemeter	Chamber	N_k (Gy/C)	$N_{D,W}$ (Gy/C)	$N_{D,W}/N_k$
NE 2590A, SN 223	NE 2571, SN 1633	4.155×10^7	4.527×10^7	1.0895
NE 2590E, SN 360	NE 2571, SN 2289	4.170×10^7	4.556×10^7	1.0926
NE 2670A, SN 321	NE 2571, SN 3197	4.134×10^7	4.522×10^7	1.0938

For electron beams, the cross calibration of PTW 23343 Markus chamber with 0.6 cc thimble chamber were performed to determine $N_{D,W}$ of the highest energy of electron beams (20-22 MeV). The beam size was 10x10 cm. For a new IAEA protocol, the chamber was placed at the reference depth (Z_{ref}) which equals to $0.6\,R_{50} - 0.1$ cm for plane-parallel chamber and at $Z_{ref} + 0.5$ radius of chamber for 0.6 cc chamber while for TRS 277 protocol the chamber was placed at the depth of maximum dose. When the $N_{D,W}$ was determined, the calibration of the highest energy electron beams was performed. The measurement was undertaken for both protocols at maximum field size, which two hospitals used 25x25 cm and the other one used 15x15 cm. The position of the chamber was at the depth as stated above.

The absorbed dose to water was calculated by following equations:

TRS 277 $D_{w,Q} = M_Q N_{D,air} (S_{W,air})_Q \, p_Q$ ——1

TRS 398 $D_{w,Q} = M_Q N_{D,W,Q0} k_{Q,Q0}$ ——2

M_Q is the reading of dosimeter corrected for recombination and environment condition.

$N_{D,air}$ is the absorbed dose to air chamber factor base on air kerma, $(S_{W,air})_Q$ is the stopping power ratio water to air at the user's quality at the point of interest and p_Q is the perturbation correction factor.

$N_{D,W,Q0}$ is the calibration factor in term of absorbed dose to water at a reference beam quality Q_0 and $k_{Q,Q0}$ is a chamber specific factor which corrects for differences between the reference beam quality Q_0 and the actual beam quality Q.

RESULTS

The ratio of the calibration factors of N_K and $N_{D,W}$ determined by the SSDL which are shown in table 2 for three hospitals are in the same range. The variation between the chambers is less than 1%. Table 3 shows the comparison of the absorbed dose to water at $D_{max.}$ between TRS 398 and TRS 277 for 6 and 10 MV together with the beam parameters used for absorbed dose determination, while Table 4 shows the comparison of the absorbed dose to water at $D_{max.}$ between TRS 398 and TRS 277 for Cobalt-60 gamma rays and also the beam parameters. King Chulalongkorn Memorial and Siriraj hospital set the center of the beams at the center of the chamber (TRS 398) while Ramathibodi hospital set the measurement point at effective points (TRS 277) which are shifted from the center of chamber toward the surface. All the hospital made the measurement only one depth and used this data to determine the absorbed dose both in TRS 277 and TRS 398. The percentage depth dose at depth were used to calculate the absorbed dose to water at $D_{max.}$, the depth and percentage depth dose for each protocol are also shown in Table 3 and Table 4. The ratio of the absorbed dose to water at $D_{max.}$ determined by TRS 398 and TRS 277 for photon beams are mostly higher than TRS 277. The maximum discrepancy is 0.9%

for all energy and beam studied.

For electron beams, Table 5 shows the types of chamber and the cross calibration factor of electron beams. Table 6 shows the comparison of the absorbed dose to water at D_{max} determined by TRS 398 and TRS 277 for the large field size and high energy electron beams. The discrepancy between TRS 277 and TRS 398 protocol is as high as 5% for one of the three hospitals.

Table 3. Comparison of the absorbed dose to water at $D_{max.}$ (cGy/mu) for TRS 398 and TRS 277 of 6 and 10 MV x-ray beams,10x10 cm,100 cm SSD The absorbed doses at the depth of measurement are also shown, with the parameters used for dose determinations.

Unit	Energy (MV)	TRS 277					TRS 398				TRS 398/277
		$TPR_{20,10}$	Depth (cm)	%DD %	D_{ref} *	D_{max} **	Depth (cm)	%DD (%)	D_{ref} *	D_{max} **	
Clinac1800	6	0.6770	4.80	87.40	0.895	1.024	5.0	86.60	0.885	1.022	0.998
Clinac 2100C	6	0.6725	5.00	87.08	0.856	0.983	5.2	86.27	0.850	0.985	1.002
Clinac 23EX	6	0.6720	4.80	86.58	0.875	1.011	5.0	85.30	0.870	1.020	1.009
Clinac 1800	10	0.7380	9.80	74.50	0.753	1.011	10.0	73.70	0.748	1.015	1.004
Clinac 2100C	10	0.7353	10.00	73.65	0.728	0.988	10.2	73.05	0.725	0.993	1.005
Clinac 23EX	10	0.7381	9.80	73.68	0.742	1.007	10.0	73.00	0.739	1.012	1.005

* D_{ref} = Absorbed dose in cGy/mu at the reference depth of measurements
** D_{max} = Absorbed dose in cGy/mu at the depth of maximum dose

Table 4. Comparison of the absorbed dose to water at $D_{max.}$ (cGy/mu) for TRS 398 and TRS 277 of Co-60 gamma beams, 10x10 cm, 100 cm SSD.

Unit	Energy (MeV)	TRS 277				TRS 398				TRS 398/277
		Depth (cm)	%DD (%)	D_{ref}	D_{max}	Depth (cm)	%DD (%)	D_{ref}	D_{max}	
Co-60 Elite	1.25	4.80	79.50	166.40	209.31	5.0	78.25	164.12	209.74	1.002
Co-60 780C	1.25	5.00	78.80	85.73	108.79	5.2	77.82	84.78	108.94	1.001
Co-60 780C	1.25	4.80	79.17	169.70	214.35	5.0	78.40	168.27	214.63	1.001

Table 5. Type of chambers and calibration factors for electron measurement.

Dosemeter	Chamber	N_k (Gy/C)	$N_{D,W(cross)}$ (Gy/C)
NE 2590A, SN 223	PTW 23343, SN 1042	4.708×10^8	4.628×10^8
NE 2590E, SN 360	PTW 23343, SN 2380	4.968×10^8	4.690×10^8
NE 2670A, SN 321	PTW 23343, SN 3485	5.044×10^8	5.232×10^8

Table 6. Comparison of the absorbed dose to water at $D_{max.}$ (cGy/mu) for TRS 398 and TRS 277 of electron beams, 100 cm SSD

Unit	Energy (MeV)	Field size (cm)	TRS 277		TRS 398				TRS 398/277
			d_{max} (cm)	D_{max} (cGY/mu)	Z_{ref} (cm)	%DD (%)	D_{ref} (cGy/mu)	D_{max} (cGy/mu)	
Clinac 1800	20	25x25	2.00	0.848	5.00	96.0	0.8120	0.846	0.997
Clinac 2100C	20	25x25	2.80	0.90116	5.10	94.5	0.8109	0.858	0.952
Clinac 23EX	22	15x15	2.64	1.01020	5.19	95.5	0.9774	1.023	1.013

DISCUSSION AND CONCLUSION

This paper presents results of measurements of absorbed dose to water in high energy photon and electron beams following the recommendations of TRS 398 and TRS 277. The variation of $N_{D,W} / N_K$ for three hospitals is less than 1%. The absorbed dose for photon beams show the agreement for both protocol with the maximum discrepancy of 0.9%. Most of the results show the higher dose for TRS 398 than TRS 277. For electron beams,the procedure may be complicated with many changes for measurement and for the absorbed dose determination. So the discrepancy is going up to 5%. Huq[3] reported the results for photon beams using TRS 398 are about 1% larger than those obtain with TRS 277 for most commonly used clinical beam qualities. For electron beam quality range of 2.27-8.13 cm, a maximum discrepancy of about 2% are observed between TRS 398 and TRS 277. Our study for photon beams are comparable to Huq' s report but not for electrons. However, these measurements are the experimental study and the implementation of TRS 398 in the clinical for all institutes in the country will be continued with the assistance of SSDL and IAEA in term of expert and documents.

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