# COMPARISON OF ABSORBED DOSE FOR HIGH ENERGY PHOTON BEAMS DETERMINATION BY IAEA TRS 398 AND IAEA TRS 277 FOR 8 HOSPITALS IN BANGKOK

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## ABSTRACT

Absorbed dose to water is of great important in radiation therapy. The IAEA TRS 277 protocol using an ionization chamber calibrated in air in term of air kerma has been used for absorbed doses determination in all therapy centers in Thailand. In recent year, a new code of practice IAEA TRS 398 based on chamber calibration in term of absorbed doses to water was introduced to reduce uncertainties arising from calculation of absorbed dose to water using air kerma calibration factor. To implement this new protocol into a clinic, a comparison of the two protocols should be studied. The study was undertaken for 8 hospitals in Bangkok with 6, 10 and 18 MV x-ray beams from linear accelerators and gamma beams from Co-60 machines. The measurements were made in a water phantom at the reference depth as specified in the protocols with two types of dosemeter system, one was the control dosemeter and the other was the hospital dosemeters. The results showed that the absorbed dose determined by TRS 398 and TRS 277 were agreeable within 1% for all energies of photon beams in 8 hospitals. The result is consistent with other studies. The hospital dosemeters showed a maximum discrepancy of 0.7%, 0.7%, 0.5% and 0.5% for 6, 10 and 18 MV x-ray beams and Co-60 beams, respectively, The absorbed doses measured from the control dosemeter were comparable to the hospital dosemeters within 1.8%. Agreement between control dosemeter and hospital dosemeter with TRS 398 is slightly better than the agreement with TRS 277. A transition from TRS 277 to TRS 398 would not significantly change the absorbed dose values of high energy photon beams. The new protocol could be implemented to all of the hospitals in this project with confidence.

## INTRODUCTION

Implementation the new International Atomic Energy Agency (IAEA) code of practice of Technical Reports Series No.398[1] in Thailand was encouraged by the Secondary Standard Dosimetry Laboratory (SSDL), Division of Radiation and Medical Devices, Department of Medical Sciences, Ministry of Public Health. The calibration factor in term of absorbed dose to water was provided for the requested chamber. During preparing to implement the new code of practice, the SSDL supplied both the absorbed dose to water calibration factor (ND,W) and the air kerma calibration factor (NK) for the hospitals that

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interested to use new code of practice. The aim of this study is to compare the dose determined by the new code of practice (TRS 398) with the dose determined by the old code of practice (TRS-277)[2] which has been used previously in all therapy center in Thailand.

## MATERIALS AND METHODS

This study was undertaken at eight hospitals in Bangkok. The beams were 6, 10 and 15 MV x-rays and Cobalt-60 gamma rays. The types of the beams and machines which were employed in this study are shown in Table 1. The types of all dosemeter system and their calibration factors for photon beams are shown in Table 2. All chamber were calibrated at SSDL in term of $N_K$ and $N_{D,W}$. All the chambers are NE 2571 cylindrical chamber. The ratio of $N_{D,W}$ and $N_K$ showed less variation for the same type of chamber, the difference was less than 0.4%. The dosemete of Hospital. A which was belong to the authors was used as a control, it measured the dose for all beams in this study together with the own dosemeter of the hospitals.

The measurements were performed for field size 10x10 cm$^2$ at 100 cm SSD for linear accelerator and 80 cm SSD for Co-60 machine. Types and dimension of the water phantoms and beam directions for all hospitals are shown in Table 3. The IAEA TRS 277 protocol recommended the measurement at the effective point which is displaced from the middle of the chamber equals to 0.6 times of the middle of the radius of the chamber. The reference depths are 5 cm for 6 MV photon beams and Co-60 beams and 10 cm for 10 MV and 18 MV photon beams. The TRS 398 recommended the measurement at the center of the chamber, the reference depths are 5 cm and 10 cm for Co-60 beams and photon beam of all energies, respectively. The absorbed dose to water was calculated by following equation.

TRS 277 $$D_W(P_{eff}) = M_Q N_{D,air} (S_{w,air})P_Q \quad ....(1)$$

TRS 398 $$D_{W,Qo} = M_Q N_{D,W,Qo} k_{Q,Qo} \quad ....(2)$$

$M_Q$ is ionization charge reading from electrometer that already corrects to yield the influence corresponding to the reference 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. $N_{D,W,Qo}$ is the calibration factor in term of absorbed dose to water at reference beam quality $Q_0$ and $k_{Q,Qo}$ is a chamber specific which corrects for differences between the reference beam quality $Q_0$ and the actual beam quality Q.

The absorbed dose to water at the depth of maximum dose was calculated by percent depth dose at the depth which chamber was placed after the absorbed dose to water at the reference depth was measured and calculated.

**Table 1** Types of the linear accelerator machines with photon beam energies and types of Co-60 machines.

| Hospital | Linear Accelerator | X-ray beams | | | Co-60 Machine |
|---|---|---|---|---|---|
| | | 6 MV | 10 MV | 18 MV | |
| A | Clinac 1800 | ✓ | ✓ | - | Theratron 80Elite |
| B | Clinac 2100C | - | ✓ | - | Theratron 780C |
| C | Clinac 23EX | ✓ | ✓ | - | Theratron 780C |
| D | Philips SL20 | ✓ | - | ✓ | - |
| E | Philips SL20 | ✓ | - | ✓ | - |
| F | Philips SL15 | ✓ | ✓ | - | - |
| G | Philips SL15 | ✓ | ✓ | - | - |
| H | - | - | - | - | Theratron Pheonix |

**Table 2** Types of ionization chamber and electrometer of eight hospitals (A-H) for photon beam measurements with the calibration factors that supplied by SSDL both in $N_K$ and $N_{D,W}$ and the ratio of $N_{D,W}$ $/N_K$.

| Hospital | Chamber | Dosemeter | $N_k$(Gy/C) | $N_{d,w}$(Gy/C) | $N_{D,W}$ / $N_k$ |
|---|---|---|---|---|---|
| A | NE2571, SN1633 | NE2590A, SN 223 | $4.155 \times 10^7$ | $4.527 \times 10^7$ | 1.0895 |
| B | NE2571, | NE2590E, SN2289 | $4.170 \times 10^7$ SN360 | $4.556 \times 10^7$ | 1.0926 |
| C | NE2571, SN3197 | NE2670A, SN321 | $4.134 \times 10^7$ | $4.522 \times 10^7$ | 1.0939 |
| D | NE2571, SN2697 | NE2570/1, SN1133 | $4.120 \times 10^7$ | $4.050 \times 10^7$ | 1.0934 |
| E | NE2571, SN2378 | NE2570/1, SN1135 | $4.073 \times 10^7$ | $4.448 \times 10^7$ | 1.0921 |
| F | NE2571, SN2784 | NE2570/1B, SN1134 | $4.112 \times 10^7$ | $4.494 \times 10^7$ | 1.0929 |
| G | NE2571, SN2472 | NE2570/1B, SN1145 | $4.177 \times 10^7$ | $4.555 \times 10^7$ | 1.0904 |
| H | NE2571, SN1465 | NE2570/1B, SN 767 | $4.148 \times 10^7$ | $4.532 \times 10^7$ | 1.0924 |

**Table 3** Types of the water phantom, their dimension and beam direction to the phantom for eight hospitals.

| Hospital | Phantom | Dimension ($cm^3$) | Beam direction |
|---|---|---|---|
| A | NE model 2545/3A | 30x30x25 | Vertical |
| B | Radiation product design model 692/000D | 35x37x40 | Horizontal |
| C | Med-Tec model 150 | 40x40x40 | Vertical |
| D | Med-Tec model 150 | 40x40x40 | Vertical |
| E | NE model 2545/3A | 30x30x25 | Vertical |
| F | NE model 2545/3A | 30x30x25 | Vertical |
| G | Home made | 40x40x40 | Vertical |
| H | PTW model T41014 | 20x20x10 | Vertical |

## RESULTS AND DISCUSSION

### A. The comparison of the absorbed doses to water between IAEA TRS 398 and TRS 277

The comparison of absorbed doses to water measured by hospital dosemeter at depth of maximum doses for 6, 10, 18 MV x-ray beams and Co-60 gamma beams of eight hospitals in Bangkok, Thailand are presented in table 4 (a-d). Dose ratios are presented for the discrepancies between the two protocols.

The ratios of the absorbed dose to water at depth of maximum dose between IAEA TRS 398 and TRS 277 showed the maximum difference of less than 1% for all energies of x-ray beams in eight hospitals. The maximum difference were 0.7%, 0.7%, 0.5%, and 0.5% for 6, 10, 18 MV x-ray beams and Cobalt-60 gamma beams, respectively. Most of the results showed the higher dose for TRS 398 than TRS 277. These are agreeable with Huq[4] who concluded the differences of about 1% between these two protocols. The differences arise due to inaccuracies in the numerical factors and expressions (for example $k_m$, $P_{wall}$, etc.) in the $N_k$ based method and, to a lesser extent, in IAEA TRS 398. The other cause of differences is the primary standard to which the calibrations in term of air kerma and absorbed dose to water are traceable.[1]

In addition, the new code of practice is more practical to be used than the old code of practice. The parameters used in the new code of practice are simple and more accurate, these reduce the possibility of errors in the determination of absorbed doses to water in the radiation beam.

**Table 4 (a-d).** Comparison of the absorbed dose to water between TRS 398 and TRS 277 at the depth of maximum dose

(a) 6 MV x-ray beams

| Machine | $TPR_{20,10}$ | IAEA TRS 277 $D_{max}$ (cGy/min) | IAEA TRS 398 $D_{max}$ (cGy/min) | Ratio of TRS 398/277 |
|---|---|---|---|---|
| Clinac 1800 | 0.6748 | 0.999 | 1.003 | 1.004 |
| Clinac 23EX | 0.6719 | 1.004 | 1.011 | 1.007 |
| Philips SL20 | 0.6800 | 0.999 | 0.998 | 0.999 |
| Philips SL20 | 0.6826 | 1.005 | 1.003 | 0.998 |
| Philips SL15 | 0.6830 | 1.006 | 1.001 | 0.995 |
| Philips SL15 | 0.6733 | 0.992 | 0.991 | 0.999 |

(b) 10 MV x-ray beams

| Machine | $TPR_{20,10}$ | IAEA TRS 277 $D_{max}$ (cGy/min) | IAEA TRS 398 $D_{max}$ (cGy/min) | Ratio of TRS 398/277 |
|---|---|---|---|---|
| Clinac 1800 | 0.7380 | 1.009 | 1.010 | 1.001 |
| Clinac 2100C | 0.7356 | 0.991 | 0.998 | 1.007 |
| Clinac 23EX | 0.7401 | 1.005 | 1.012 | 1.007 |
| Philips SL15 | 0.7352 | 0.959 | 0.965 | 1.006 |
| Philips SL15 | 0.7369 | 0.989 | 0.990 | 1.001 |

(c) 18 MV x-ray beams

| Machine | $TPR_{20,10}$ | IAEA TRS 277 $D_{max}$ (cGy/min) | IAEA TRS 398 $D_{max}$ (cGy/min) | Ratio of TRS 398/27 |
|---|---|---|---|---|
| Philips SL20 | 0.7800 | 0.997 | 1.002 | 1.005 |
| Philips SL20 | 0.7805 | 1.010 | 1.015 | 1.005 |

(d) Cobalt-60 gamma beams

| Machine | IAEA TRS 277 $D_{max}$ (cGy/min) | IAEA TRS 398 $D_{max}$ (cGy/min) | Ratio of TRS 398/277 |
|---|---|---|---|
| Theratron 80Elite | 156.50 | 156.25 | 0.998 |
| Theratron 780 C | 83.62 | 83.84 | 1.003 |
| Theratron 780 C | 286.45 | 287.83 | 1.005 |
| Theratron Phoenix | 230.42 | 230.81 | 1.002 |

$D_{max}$ = Absorbed dose at the maximum dose

**B. The comparison of the absorbed dose to water between control dosemeter and hospital dosemeter**

The comparison of the absorbed doses at depth of maximum dose using the control dosemeter and hospital dosemeter determined by IAEA TRS 277 and TRS 398 are shown in table 5(a-d) for 6, 10, 18 MV x-ray beams and cobalt-60 gamma beams, respectively. The absorbed doses at depth of maximum dose between the control dosemeter and the hospital dosemeter for TRS 277 showed the agreeable with the maximum differences of 0.7%, 1.5%, 0.6% and 1.8% for 6, 10, 18 MV x-ray beams and Cobalt-60 gamma beams, respectively, while using TRS 398, the maximum differences were 0.7%, 1.1%, 0.3% and 1.4% for 6, 10, 18 MV x-ray beams and Cobalt-60 beams, respectively. Agreement between control dosemeter and hospital dosemeter with TRS 398 is slightly better than the agreement with TRS 277. All of the control values were higher than hospital values.

The differences of beam output measured by control and hospital dosemeter were due to many factors such as differences of dosemeter, phantom type and beam orientation. Because of the variety of auxiliary dosimetry equipments such as phantoms, waterproofing sleeves and buildup foils, it is important that the measurement setup between two sets of equipment should be identical as close as possible. However, the types of water phantom affect the output reading. The small phantom (20x20x10 $cm^3$) made lower charge readings than phantom of standard size (30x30x25 $cm^3$). The stability of the dosemeter system should be arranged before making the measurement. The leakage current should be measured. The leakage current should not exceed 0.5% of minimum input current to be measured.

The mechanical QA check of linear accelerator and Co-60 machine need to be performed before the dose measurements. Many machines showed the shift of laser beams in the lateral wall and it caused the difficulties in the set up of the chambers, took long time and may cause error in the chamber position. The dose measurement is a work that needs an experienced physicist, good quality of instruments and protocol.

**Table 5 (a-d).** Compariso of the absorbed dose to water at depth of maximum dose (cGy/min for x-ray beams and cGy/min for gamma beams) between control dosemeter and hospital dosemeter following to IAEA TRS 277 and TRS 398 for 6, 10, 18 MV x-ray beams and Cobalt-60 gamma beams.

(a) 6 MV x-ray beams

| Machine | IAEA TRS 277 | | | IAEA TRS 398 | | |
|---|---|---|---|---|---|---|
| | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H | Control dosemeter | Hospital dosemeter | Ratio C/H |
| Clinac 1800 | 0.999 | 0.999 | 1.000 | 1.003 | 1.003 | 1.000 |
| Clinac 23EX | 1.011 | 1.004 | 1.007 | 1.012 | 1.011 | 1.001 |
| Philips SL20 | 0.999 | 0.992 | 1.007 | 0.998 | 0.991 | 1.007 |
| Philips SL20 | 1.010 | 1.005 | 1.004 | 1.006 | 1.003 | 1.003 |
| Philips SL15 | 1.010 | 1.006 | 1.004 | 1.003 | 1.001 | 1.002 |
| Philips SL15 | 0.995 | 0.992 | 1.003 | 0.990 | 0.991 | 0.999 |

(b) 10 MV x-ray beams

| Machine | IAEA TRS 277 | | | IAEA TRS 398 | | |
|---|---|---|---|---|---|---|
| | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H |
| Clinac 1800 | 1.009 | 1.009 | 1.000 | 1.010 | 1.010 | 1.000 |
| Clinac 2100C | 1.006 | 0.991 | 1.015 | 1.009 | 0.998 | 1.011 |
| Clinac 23EX | 1.009 | 1.005 | 1.004 | 1.012 | 1.012 | 1.000 |
| Philips SL15 | 0.963 | 0.959 | 1.004 | 0.966 | 0.965 | 1.001 |
| Philips SL15 | 0.990 | 0.989 | 1.001 | 0.988 | 0.990 | 0.998 |

(c) 18 MV x-ray beams

| Machine | IAEA TRS 277 | | | IAEA TRS 398 | | |
|---|---|---|---|---|---|---|
| | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H |
| Philips SL20 | 0.997 | 0.996 | 1.001 | 1.002 | 0.999 | 1.003 |
| Philips SL20 | 1.016 | 1.010 | 1.006 | 1.018 | 1.015 | 1.003 |

(d) Cobalt-60 beams x-ray beams

| Machine | IAEA TRS 277 | | | IAEA TRS 398 | | |
|---|---|---|---|---|---|---|
| | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H | Control (C) dosemeter | Hospital (H) dosemeter | Ratio C/H |
| Theratron 80 Elite | 156.50 | 156.50 | 1.000 | 156.25 | 156.25 | 1.000 |
| Theratron 780 C | 85.14 | 83.62 | 1.018 | 84.70 | 83.84 | 1.010 |
| Theratron 780 C | 289.75 | 286.45 | 1.011 | 290.26 | 287.83 | 1.005 |
| Theratron Phoenix | 233.85 | 230.42 | 1.015 | 233.99 | 230.81 | 1.014 |

## CONCLUSIONS

It is concluded from the results of this experiment that :

(1) The absorbed doses to water determined by the IAEA TRS 398 protocol in comparison with the IAEA TRS 277 for all hospitals showed a variation of less than 1% with all beam energies. Most of the absorbed doses to water determined by the TRS 398 were slightly higher than the absorbed doses

determined by the TRS 277. The results are similar to that obtained from the Huq[4,5] and Andreo[6] studies.

(2) The absorbed doses measured by the control dosemeter showed agreement with the hospital dosemeters with the maximum differences of 1.8%. Most of the doses measured by control dosemeter were higher than the doses measured by hospital dosemeters.

(3) TRS 398 relied on ion chamber calibration in a water phantom with Co-60 gamma beams; as a result, photon beam calibrations with different chambers were slightly better agreement using TRS 398 than using TRS 277.

(4) The consistencies of the experimental studies indicate the potential to implement the new protocol, TRS 398 to determine the absorbed dose of the photon beams in Thailand.

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