

## ABSTRACT

**COMPARISON BETWEEN TG-51 AND TG-21: THE RESULTS OF TG-51 BETA TESTING.** J.R. Lowenstein, S.H. Cho, P.A. Balter and W.F. Hanson, Dept. of Radiation Physics, The University of Texas M.D. Anderson Cancer Center, Houston, TX 77030

A new protocol for clinical reference dosimetry of external beam radiation therapy, has been developed by the AAPM Task Group 51 (TG-51) to replace the previous protocol (TG-21). The TG-51 protocol is based on an absorbed dose to water calibration factor ( $N_{D,w}$ ) and an energy-dependent correction factor,  $k_Q$ . The TG-21 protocol is based on an exposure (air kerma) standard and multiple energy-dependent correction factors. Because of these dosimetry differences, and the incorporation of updated physical data, the results of clinical reference dosimetry based on TG-51 are expected to be somewhat different from those based on TG-21. The Radiological Physics Center (RPC) has conducted a systematic comparison between these two protocols, in which photon and electron outputs following both protocols are compared under identical conditions. Multiple chamber types (cylindrical) used in this study were selected from the list given in the TG-51 report, covering the majority of current manufacturers. Comparison shows discrepancies somewhat larger than expected, 1% or more difference for all beams for some chambers.

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## METHODS

- Measurements were made with cylindrical ionization chambers on a Varian Clinac 2100C for 6 MV and 18 MV photons and 9 MeV and 16 MeV electrons. The makes and models of cylindrical ionization chambers presented reflect those most commonly used (from the list given by TG-51 report).
  - NEL 2571
  - PTW N23333 / N30001
  - Capintec PR06C
  - Exradin A12
- Outputs were determined in water following TG-51 and TG-21 calibration protocols.
  - Photons :  
Measured at a depth of 10 cm for TG-21 and TG-51. Compared TG51/TG21 at  $d_{ref}$  (i.e., 10 cm depth ).
  - Electrons :  
Measured at  $d_{ref}$  for TG-51 and at  $d_{max}$  for TG-21. Compared TG51/TG21 at  $d_{ref}$ .
- Waterproofing material used for the ionization chambers was  $\leq 1$  mm of PMMA.
- The  $N_{D,w}$  and  $N_K$  values for each chamber were determined by the M.D. Anderson ADCL based on standards obtained from NIST.

## Compare Dose & Kerma Standards

- The equation used to determine  $N_{D,w}/N_K$  is as follows:

$$\frac{N_{D,w}}{N_K} = (0.8791)^{-1} \left( \frac{N_{\text{gas}}}{N_X} \right) (P_{\text{repl}}) (P_{\text{wall}}) \left( \frac{L}{\rho} \right)_{\text{air}}^{\text{water}} \quad \text{Eq. (1)}$$

- where  $P_{\text{repl}}$ ,  $P_{\text{wall}}$  and  $L/\rho$  values were taken from TG-21 data and  $N_{\text{gas}}/N_X$  comes from Gastorf et al.

## Photon Equations

- The equations used to determine absorbed dose for photons are as follows:

- TG-21

$$D_{\text{water}} = \left( \frac{M}{U} \right) (N_{\text{gas}}) \left( \frac{L}{\rho} \right)_{\text{air}}^{\text{water}} (P_{\text{wall}}) (P_{\text{ion}}) (P_{\text{repl}})$$

- TG-51

$$D_W^Q = (P_{\text{ion}}) (P_{\text{TP}}) (P_{\text{elec}}) (P_{\text{pol}}) (M_{\text{raw}}) (k_Q) \left( N_{D,w}^{60\text{Co}} \right)$$

## Electron Equations

- The equations used to determine dose for electrons are as follows:

Both values are absorbed dose at  $d_{\text{ref}}$ .

- TG-21

$$D_{\text{water}} = \left( \frac{M}{U} \right) (N_{\text{gas}}) \left( \frac{L}{\rho} \right)_{\text{air}}^{\text{water}} (P_{\text{ion}}) (P_{\text{repl}}) \left( \frac{\% \text{ dd } (d_{\text{ref}})}{\% \text{ dd } (d_{\text{max}})} \right)$$

- where %dd was determined using data and procedures in TG-25.

- TG-51

$$D_W^Q = (P_{\text{ion}}) (P_{\text{TP}}) (P_{\text{elec}}) (P_{\text{pol}}) (M_{\text{raw}}) (P_{\text{gr}}^Q) (k'_{R50}) (k_{\text{ecal}}) \left( N_{D,w}^{60\text{Co}} \right)$$

### TG-51 Photon Measurements

- Search for  $d_{\max}$  (apply a  $0.6 r_{\text{cav}}$  shift to effective point of measurement).
- Place chamber at  $10\text{cm} + 0.6 r_{\text{cav}}$  to determine PDD at 10 cm.
- Determine  $k_Q$  value using the data from TG-51 report.
- Move chamber to calibration, 10 cm, depth (without a  $0.6 r_{\text{cav}}$  shift).
- Make measurements for Polarity Correction (+ 300 and – 300 Volts) and Pion (- 150 Volts).
- Polarity Correction was less than 0.2% for all chambers studied.

### TG-51 Electron Measurements

- Search for  $I_{\max}$  and  $I_{50}$  (apply a  $0.5 r_{\text{cav}}$  shift to effective point of measurement).
  - From these; determine  $R_{50}$  and  $d_{\text{ref}}$ .
  - From  $R_{50}$ ;  $k'_{R50}$  is determined.
- Move center of chamber to the calibration depth,  $d_{\text{ref}}$  (without a  $0.5 r_{\text{cav}}$  shift).
- Measure Polarity Correction (+ 300 and – 300 Volts) and  $P_{\text{ion}}$  (- 150 Volts).
- Move center of chamber to  $d_{\text{ref}} + 0.5r_{\text{cav}}$  and calculate the gradient correction;  $P_{\text{gr}}^Q$
- Polarity correction was less than 0.2% for all chambers studied.

## RESULTS

The first consideration is to compare Standards, at  $^{60}\text{Co}$

**Air Kerma Standard:** based on **Graphite ion chambers** measuring **in-air**.

$N_K$   $^{60}\text{Co}$  Air Kerma Calibration Factor. Transferred to Ion chambers from the Standard maintained at NIST or NRC Canada.  
(The Exposure Calibration factor,  $N_X$ , is used in TG-21:  $N_X = N_K/0.879$ )

**Absorbed Dose Standard:** based on **Water Calorimetry** at **depth**.

$N_{D,w}$   $^{60}\text{Co}$  Absorbed Dose Calibration Factor. Transferred to Ion Chambers from the standard maintained at NIST or NRC Canada.

### Comparison Between Absorbed Dose and Air Kerma Calibration

| Chamber                  | $N_{D,w}/N_K$ | $N_{D,w}/N_K$ | Meas/Calc |
|--------------------------|---------------|---------------|-----------|
|                          | (Meas.)       | (Calc.)       |           |
| NEL 2571                 | 1.101         | 1.088         | 1.012     |
| PTW<br>N23333/N300<br>01 | 1.099         | 1.086         | 1.012     |
| Capintec<br>PR06C        | 1.095         | 1.079         | 1.015     |
| Exradin A12              | 1.106         | 1.093         | 1.011     |

**Table 1:** Ratio of the Absorbed Dose Calibration factor to the Air Kerma Calibration factor for two conditions (Using NIST standards):

- (Measured)  $N_{D,w}$  and  $N_K$  both assigned to the Chamber.
- (Calculated)  $N_K$  assigned to the chamber, and  $N_{D,w}$  calculated from  $N_K$  using Equation 1.

The 1.2% discrepancy between the measured and calculated values represents a basic discrepancy between the Air Kerma and Absorbed dose standards and the TG-21 formalism used to convert Air Kerma into Dose. NIST and NRC Canada are aware of a 0.7% difference between their two Air Kerma standards. This difference is in the right direction to suggest that  $N_{D,w} / N_K$  for NRC Canada should be closer to unity.

### Comparison Between TG-51 and TG-21 Calibrations (photons)

| Chamber           | 6 MV<br>TG51/TG21 | 18 MV<br>TG51/TG21 |
|-------------------|-------------------|--------------------|
| NEL 2571          | 1.010             | 1.007              |
| PTW N23333/N30001 | 1.013             | 1.014              |
| Capintec PR-06C   | 1.011             | 1.009              |
| Exradin A12       | 1.008             | 1.004              |

Remark: Presented results have an uncertainty of less than  $\pm 0.4\%$ .

**Table 2:** Ratio of the absorbed dose to water determined (from measurements at 10 cm depth in water) using the AAPM TG-51 and AAPM TG-21 calibration protocols. The 1% discrepancy between the TG-51 and TG-21 doses is primarily due to the differences in the two standards discussed in Table 1.

### Comparison Between TG-51 and TG-21 Calibrations (electrons)

| <u>Chamber</u>   | <u>9 MeV<br/>TG51/TG21</u> | <u>16 MeV<br/>TG51/TG21</u> |
|------------------|----------------------------|-----------------------------|
| NEL 2571         | 1.015                      | 1.021                       |
| PTW N2333/N30001 | 1.014                      | 1.017                       |
| Capintec PR06C   | 1.014                      | 1.015                       |
| Exradin A12      | 1.014                      | 1.016                       |

**Table 3:** Ratio of the absorbed dose to water (at  $d_{ref}$ ) determined using the AAPM TG-51 and AAPM TG-21 calibration protocols. Again 1% of the discrepancy is understood from Table 1. The remaining 0.5% to 1% discrepancy is partially due to new stopping power data used for the TG-51 protocol.

### Conclusions

Standards:

- There is an apparent 1% discrepancy between the Absorbed Dose Standard and the Air Kerma Standard (converted to dose using TG-21).

Photons:

- Institutions, which calibrate at  $d_{max}$  for TG-21, may see a different TG51/TG21 ratio, due to the difference in the determination of  $\%dd$  for TG-51 and TG-21.
- The 1% discrepancy in the standards is reflected in a 1% discrepancy between TG-51 and TG-21 for x-rays.

Electrons:

- In addition to the 1% discrepancy in standards there is an additional discrepancy for electrons, partly due to new stopping power data used for the TG-51 protocol.
- The magnitude of changes in electron beam output may depend on the electron energy.

### Helpful Hints

- In a student laboratory two nights were required to complete measurements (photons and electrons) and calculations for TG-51. Three nights were required to complete measurements (photons and electrons) and calculations for TG-21.
- For photons there was a short learning curve to overcome (one evening).
- For electrons there was a longer learning curve to overcome (several long evenings).
- It is important when you convert to TG-51 to assess the change this will make in your dosimetry. The change should be less than 2% if TG-51 and TG-21 are followed explicitly.
- Since TG-51 and TG-21 depend on separate standards, there may be additional uncertainties depending upon when and where the two calibrations were obtained.

**If you experience more than a 2% discrepancy between TG-51 and TG-21 contact the RPC. We will discuss it with you (713) 792-3226.**