Changing from TG21 to TG51 in the Department of Radiation Oncology at the University of Michigan

Lars Ewell, August 28, 2002

Introduction

Of paramount concern in the field of radiation oncology is the accurate measurement of the amount of radiation that is delivered to the treatment site. The concept of radiation *dose*[1] has been beneficial in helping to more accurately measure how much and what type of radiation is best utilized in a given treatment.

Over time, changes have occurred as empirical knowledge is gained and different machines are commissioned. Here in the Department of Radiation Oncology at the University of Michigan, these changes have led to a divergence of calibration procedures for different radiation therapy machines. This divergence has made comparisons between different machines more difficult, and has added complexity, which in turn has increased the probability of error.

In an attempt to simplify machine calibration, a new protocol, Task Group 51 (TG51)[2], has been developed by the American Association of Physicists in Medicine (AAPM). This is meant to replace TG21[3, 4].

It is the intent of this document to provide information that will facilitate change from the present TG21 protocol to TG51 here in the Department of Radiation Oncology at the University of Michigan.

TG51 vs. TG21

An important point involving dosimetry measurements is the fact that the detectors (ion chambers) used to make them are required to be calibrated by an Accredited Dosimetry Calibration Laboratory (ADCL). This allows for uniformity of measurements and direct comparison between different institutions.

The main difference between the TG21 dosimetry protocol and TG51 is the fact that TG51 requires absorbed dose to water calibration factors. Since the clinical reference dosimetry calibrations done here at Michigan are performed in water, the TG51 protocol more closely models the types of measurements that are routinely performed during machine QA. This fact accounts for the added simplicity of TG51 vs. TG21[5] .

In addition to this main difference, the two protocols are distinguished in the method by which the beam quality (energy) is specified, as well as the reference calibration depth for electrons.

To illustrate, we can examine how an actual dose calibration is done using each of the two protocols.

[1] *The Physics of Radiation Therapy*, F. M. Kahn, Lippincott Williams and Wilkins, 1994.

[2] *AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams*, Medical Physics, Vol. 26, Issue 9, 8/99.

[3] *A protocol for the determination of absorbed dose from high-energy photon and electron beams*, Medical Physics, Vol. 10, Issue 6, 11/83.

[4] *Clarification of the AAPM Task Group 21 Protocol*, Medical Physics, Vol. 13, Issue 5, 9/86.

[5] see http://www.irs.inms.nrc.ca/inms/irs/why_use_tg51/why_use_tg51_slides.html .

TG21

When a TG21 calibration is performed, the ion chamber is returned from an ADCL with a ^{60}Co *Exposure Calibration Factor* (ECF), N_x. To obtain an N_{gas} calibration factor, the following equation from TG21 is used

$$N_{gas} = N_x \frac{k(W/e)A_{ion}A_{wall}}{(\alpha(\overline{L}/\rho)^{wall}_{air}(\overline{\mu}_{en}/\rho)^{air}_{wall} + (1-\alpha)(\overline{L}/\rho)^{cap}_{air}(\overline{\mu}_{en}/\rho)^{air}_{cap})K_{humid}}. \quad (1)$$

The reader is referred to the actual report (TG21 and Clarification) for an explanation of the many different factors in the above equation. Most of the factors are obtained from various tables and graphs in the protocol.

Once N_{gas} is determined, the dose rate at calibration depth (centiGray/Monitor Unit, cGy/MU) is obtained as follows

$$dose\ \ rate = R_{cal} = [(MK_Q N_{gas} P_{TP} P_{ion} F_{cp})/\#of MU] \quad (2)$$

with, M - reading on electrometer, K_Q - charge calibration factor (nC/Rdg), P_{TP} - temperature pressure correction, P_{ion} - ion recombination factor and, $F_{cp} = [(L/\rho)^{med}_{air} P_{wall} P_{repl}]$ a chamber-phantom factor calculated here at Michigan.

TG51

When a TG51 calibration is performed, the ion chamber is returned from an ADCL with a ^{60}Co *Absorbed Dose to Water Calibration Factor* (ADWCF), $N_{D,W}$. To obtain the dose rate at calibration depth (cGy/MU) from this factor, the following equation is used

$$dose\ \ rate = R_{cal} = Mk_Q N_{D,W}/\#of MU \quad (3)$$

with M, the corrected ion chamber reading $M = P_{ion}P_{TP}P_{elec}P_{pol}M_{raw}$.

Again, the reader is referred to the actual report (TG51) for an explanation of the different factors in the above equations.

The comparison of (1) and (2) to (3) emphasizes the simplicity of TG51 vs. TG21. It should be noted, however, that many of the factors in (1) are included in the *quality conversion factor*, k_Q, in (3) so that one should not make an absolute simplicity judgment based solely on these equations.

Although TG51 has fewer factors and is consequently less susceptible to errors, this is not meant to imply that TG51 is superior to TG21. TG21 has a wealth of information regarding dosimetry measurements and is recommended for learning purposes. In addition, TG21 is useful as a reference.

Detectors/Chambers

The different chambers and calibration factors are displayed in Table 1. As can be seen in this table, all of the chambers calibrated within the last two years have both a TG21 and a TG51 calibration. In general, the two different calibration factors are within a few percent of each other.

Table 1: TG21 and TG51 Calibration Factors

Model	Type	SN	Date	TG21 ECF (R/C)	TG51 ADWCF (Rad/C)
Exradin P11	Parallel Plate	178	6/12/01	5.347×10^9	-
Exradin P11	Parallel Plate	178	6/14/01	-	5.393×10^9
Nuc. Ent. 2571	Farmer	218	1/9/02	4.726×10^9	-
Nuc. Ent. 2571	Farmer	218	1/10/02	-	4.605×10^9
Exradin A12	Farmer	380	2/14/01	5.069×10^9	-
Exradin A12	Farmer	380	2/15/01	-	4.946×10^9
Exradin A12	Farmer	381	4/20/01	5.034×10^9	-
Exradin A12	Farmer	381	4/23/01	-	4.899×10^9
Exradin A14	Micro	170	5/3/01	2.866×10^{11}	-
Exradin A14	Micro	170	5/4/01	-	2.789×10^{11}
Nuc. Ent 2571	Farmer	710	5/17/01	4.711×10^9	-
Nuc. Ent 2571	Farmer	710	5/17/01	-	4.581×10^9

Implementation

Monthly QA

Since TG21 has been in place for some time, it is suggested that dual monthly machine calibrations take place for two months, during which time the differences between the two protocols can be evaluated. After this period, it is expected that all future dosimetry calibrations will be conducted using the TG51 protocol.

The worksheets provided in the back of the TG51 protocol[6] allow the dose rate to be calculated for both electron and photon beams. The protocol advises a 1mm sheet of Pb be used to block electron contamination when determining beam quality of the 15MV photon beam.

Parallel Plate/Cylindrical

In the past, monthly QA measurements have been done using cylindrical Farmer chambers. Due to the rapid fall off of the depth dose curve for 6MeV electrons, TG51 recommends using a parallel plate chamber at this energy. This is because the point of measurement in a parallel plate chamber is very well defined and hence can be accurately located.

However, using different chambers for different portions of the calibration procedure introduces potential errors in and of itself. In view of this, it is not yet determined whether a cylindrical chamber, a parallel plate chamber, or a combination of the two should be used when performing a dosimetry calibration.

[6]Note: There is an error in a factor of part 8a of the Photon Beam Worksheet A. Is should read

$$\left[\left(1. - \left(\frac{V_H}{V_L}\right)^2\right) \Big/ \left(\frac{M^H_{raw}}{M^L_{raw}} - \left(\frac{V_H}{V_L}\right)^2\right)\right].$$

Expectations

Cho et. al[7] did a study in which they compared the two different dosimetry protocols for a number of different ion chambers using both photon and electron beams. In particular, they tested an Exradin A12 ion chamber which has been used recently (6/02) to calibrate both the EX1 and EX2 machines here at Michigan.

Photons

For 6MV photons the five chambers that they measured had an average ratio of TG51 to TG21 output factor calibrations of 1.0098 ± 0.00088 (SD). The A12 chamber had a ratio of 1.008 ± 0.002. For 18MV photons, the corresponding numbers were 1.0048 ± 0.0018 (SD) and 1.002 ± 0.002 for the average and A12 respectively.

The measurements were performed at a 10cm water depth, like the monthly machine calibrations (except the 1800) here at Michigan.

Electrons

For electrons, the numbers are slightly higher. For 9MeV electrons the average TG51 to TG21 ratio was 1.014 ± 0.00038 (SD) and 1.014 ± 0.002 for the A12. In contrast to the photon measurements, the higher energy electron measurements had a slightly *higher* TG51 to TG21 output factor ratio. For 16MeV electrons, the average TG51 to TG21 ratio was 1.018 ± 0.0018 (SD) and 1.016 ± 0.002.

The TG21 measurements were performed at a depth of d_{max}, like the monthly machine calibrations here at Michigan. The TG51 measurements were performed at a depth of $d_{ref} = 0.6R_{50} - 0.1cm$, per the protocol, and then converted to dose rates at d_{max} using clinical depth dose data.

The results of Cho et. al are similar to another comparison performed by Huq and Andreo[8].

Conclusion

While the switch to TG51 will take some additional work during the changeover period, it is expected that once the change has been made the output calibration of the therapy machines will be completed in less time and with less probability of error.

[7] *Comparison between TG-51 and TG-21: Calibration of photon and electron beams in water using cylindrical chambers*, S. H. Cho et. al, Journal of Applied Clinical Medical Physics, Volume 1, Number 3, Summer 2000.

[8] *Reference Dosimetry in clinical high-energy photon beams: Comparison of the AAPM TG-51 and AAPM TG-21 dosimetry protocols*, M. S. Huq and P. Andreo, Medical Physics, Vol. 28, Issue 1, 1/01.