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TG-51: Common errors and helpful hints.

Since the publication of the AAPM TG-51 calibration protocol in 1999, the RPC has responded to numerous phone calls and emails about areas in the protocol where physicists have had problems. At the beginning of the year 2000, the RPC requested that institutions participating in national clinical trials provide the change in measured beam output resulting from the conversion to TG-51. The RPC has determined that as of this writing, about 770 institutions have converted to TG-51, of which just over 400 have notified us of the change in measured output. Analysis of these data revealed two significant outcomes: A large number of the reported calibration changes for photon and electron beams were outside the RPC's expected values, and the discrepancy in the reported vs. expected dose changes was as large as 8%.

The most common sources of confusion were found to be the following:

$\%dd(10)_x$: TG-51 defines photon beam quality as the percent depth dose at 10 cm depth in a 10 x 10 cm field. For photon energies ≥10 MV, depth dose should be measured with a lead foil in the beam. The measured value is called $\%dd(10)_{Pb}$. Equations 13-15 are use to calculate $\%dd(10)_x$ from the measurements. It is important to notice that the depth dose values to be used in this equation are percent depth dose, not fractional depth dose. The derived $\%dd(10)_x$ should be 0% to 2.5% greater than the measured $\%dd(10)_{Pb}$. Larger differences very likely indicate an error in calculation.

Measurement of percent depth dose: TG-51 requires that the ionization chamber be shifted to the effective point of measurement. This requires moving the ion chamber deeper in the phantom by a distance of $0.6r_{cav}$ for photons and $0.5r_{cav}$ for electrons. In fact, the shift to the effective point of measurement should be used for all relative measurements (percent depth dose, TMR, output factor, wedge transmission factor, etc.). Calibration measurements must be made without the shift, i.e., the axis of the chamber is placed at the measurement depth.

Gradient correction (P_{gr}): Equation 21 describes the procedure for calculating the correction for gradient effect, P_{gr}. The equation has been misinterpreted as requiring the product of a measurement and the depth in both the numerator and denominator. This is not correct; P_{gr} is the ratio of the measurement at $d_{ref} + 0.5r_{cav}$ divided by the measurement at d_{ref}. Another common error is to confuse the numerator and denominator; the deeper measurement must always be in the numerator. This means that for low energy electron beams, where d_{ref} is sometimes shallower than d_{max}, P_{gr} may be >1.0. At higher energies, P_{gr} is typically <1. It is never a good idea to apply the value measured one day to the calibration measurements on some other day, because an error in depth can result in a significant error in P_{gr}.

%dd correction to determine output at d_{max}: Most physicists follow the recommendations of TG-51 and correct for the %dd at the depth of measurement to determine the output at d_{max}. For photon beams, this is straightforward; the output at 10 cm depth is divided by the %dd at 10 cm depth to yield the output at d_{max}. However, a frequent source of confusion arises around the question of which %dd data to use. The clinical depth dose data must be used rather than the measurements made for determining beam quality. For electron beams, it is necessary to divide by the %dd at the depth of measurement, d_{ref}. Again, this should be the clinical value. However, an extra ionization reading at d_{max} at the time of calibration can help to assure that the clinical %dd agrees with the measured %dd within your tolerance limit. This error is an important component that shows up in the RPC's TLD results for beam output.

P_{ion}, P_{pol} measurements: A pending publication by the RPC shows that good determination of these quantities requires an adequate number of repeat readings at full, half, and reverse bias. General rules of thumb may help avoid large errors in these quantities. Generally, for a given combination of beam, linac, and ion chamber, values of these parameters should remain constant. P_{ion} increases with beam energy. For electrons, P_{ion} is somewhat larger than that for the high energy photon beam, and increases only slightly (≤0.2%) with electron energy going from lowest to higher energy. Generally, P_{pol} is observed to be significant only for low energy electrons.

A more comprehensive list of issues surrounding the implementation of TG-51 may be found in our article:

Tailor R, Hanson W, and Ibbott G, TG-51 Experience from 150 institutions, common errors, and helpful hints, *Journal of Applied Clinical Medical Physics*, 4:102-111, 2003.

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