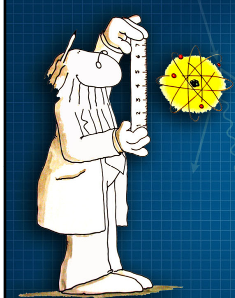

UPDATING TG-51

When will it end?

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AAPM Annual Meeting, Charlotte, 2012

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Canada

What are these updates?

Working Group review recommends:

- **Photons**:
  - i. An updated list of chambers
  - ii. Review of calculated k_Q factors
  - iii. Uncertainty analysis
  - iv. Implementation guidance notes (clarification)
- **Electrons:** More widespread revision required

AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams

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(Received 17 September 1998; accepted for publication 4 June 1999)

A protocol is prescribed for clinical reference dosimetry of external beam radiation therapy using photon beams with nominal energies between ^{60}Co and 50 MV and electron beams with nominal energies between 4 and 50 MeV. The protocol was written by Task Group 51 (TG-51) of the Radiation Therapy Committee of the American Association of Physicists in Medicine (AAPM) and has been formally approved by the AAPM for clinical use. The protocol uses ion chambers with absorbed-dose-to-water calibration factors, $N_{D,w}^{^{60}Co}$, which are traceable to national primary standards, and the equation $D_w^Q = M k_Q N_{D,w}^{^{60}Co}$, where Q is the beam quality of the clinical beam, D_w^Q is the absorbed dose to water at the point of measurement of the ion chamber placed under reference conditions, M is the fully corrected ion chamber reading, and k_Q is the quality conversion factor which converts the calibration factor for a ^{60}Co beam to that for a beam of quality Q. Values of k_Q are presented as a function of Q for many ion chambers. The value of M is given by $M = P_{ion} P_{TP} P_{elec} P_{pol} M_{raw}$, where M_{raw} is the raw, uncorrected ion chamber reading and P_{ion} corrects for ion recombination, P_{TP} for temperature and pressure variations, P_{elec} for inaccuracy of the electrometer if calibrated separately, and P_{pol} for chamber polarity effects. Beam quality, Q, is specified (i) for photon beams, by $\%dd(10)_x$, the photon component of the percentage depth dose at 10 cm depth for a field size of 10×10 cm^2 on the surface of a phantom at an SSD of 100 cm and (ii) for electron beams, by R_{50}, the depth at which the absorbed-dose falls to 50% of the maximum dose in a beam with field size ≥10×10 cm^2 on the surface of the phantom (≥20×20 cm^2 for R_{50}>8.5 cm) at an SSD of 100 cm. R_{50} is determined directly from the measured value of I_{50}, the depth at which the ionization falls to 50% of its maximum value. All clinical reference dosimetry is performed in a water phantom. The reference depth for calibration purposes is 10 cm for photon beams and $0.6R_{50} - 0.1$ cm for electron beams. For photon beams clinical reference dosimetry is performed in either an SSD or SAD setup with a 10×10 cm^2 field size defined on the phantom surface for an SSD setup or at the depth of the detector for an SAD setup. For electron beams clinical reference dosimetry is performed with a field size of ≥10×10 cm^2 (≥20×20 cm^2 for R_{50}>8.5 cm) at an SSD between 90 and 110 cm. This protocol represents a major simplification compared to the AAPM's TG-21 protocol in the sense that large tables of stopping-power ratios and mass-energy absorption coefficients are not needed and the user does not need to calculate any theoretical dosimetry factors. Worksheets for various situations are presented along with a list of equipment required. *© 1999 American Association of Physicists in Medicine.* [S0094-2405(99)00209-6]

1847 Med. Phys. 26 (9), September 1999 0094-2405/99/26(9)/1847/24/$15.00 © 1999 Am. Assoc. Phys. Med. 1847

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Part 1 - photon addendum

The report will cover the following:

A. k_Q factors for new chambers

B. Recommendations for implementation

C. Uncertainty analysis for implementation of TG-51

D. Comparison of measured and calculated k_Q factors

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TG-51 photons – what stays?

- Procedure remains unchanged
  - ✓ Continue to follow the procedure in the TG-51 document
- TG-51 remains based on a calibration coefficient obtained in Co-60
  - ✓ MV standards and calibration services are already available in certain countries but widespread dissemination in the US is not realistic at the present time.
- Calculated k_Q factors
  - ✓ Measured k_Q data are available for some chamber types
  - ✓ MV calibration services unlikely to demand in North America
- %dd(10)$_x$ remains the beam quality specifier
  - ✓ See discussion later

B. Recommendations

1. **Implementation of TG-51 Addendum**
2. **k_Q data sets**
3. **Reference-class ionization chamber**
4. **Choice of polarizing voltage**
5. **Measurement of polarity correction, P_{pol}**
6. **Effective point of measurement**
7. **Use of small volume chambers in relative dosimetry**
8. **Non-water phantoms**
9. **Application to flattening-filter-free linacs**

B.1 Implementation of Addendum

- The addendum should be implemented!
- Minor changes in experimental procedure
- New equipment may be required
- Development of uncertainty budget may take some time

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B.2 k_Q data sets

1. For chambers listed in both this addendum and the original TG-51 protocol, the k_Q factors listed in the addendum should be used.

2. For chambers that are not listed in either the original TG-51 protocol or in this addendum the recommendations of Section XI of TG-51 should be followed.

XI. USING OTHER ION CHAMBERS

This protocol provides k_Q data for the vast majority of chambers used in clinical reference dosimetry in North America as evidenced by the data on ADCL calibrations. However, other cylindrical chambers can be used by finding the closest matching chamber for which data are given. The critical features are, in order, the wall material, the radius of the air cavity, the presence of an aluminum electrode, and the wall thickness. As long as the wall material is matched and the chamber is "normal," these matching data should be accurate to within 0.5%. It is the responsibility of the user to confirm this by comparing the results to those of a calibrated cylindrical chamber for which data are given in the protocol.

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B.3 Spec for a reference chamber

Based on results in the literature we can state that *at least* the following meet this specification:

- NE2571 and NE2611
- PTW30010, PTW30012, PTW30013, PTW31013
- Exradin A12, A12S, A19, A18, A1SL
- IBA FC65-G, FC65-P, FC23-C, CC25, CC13
- Capintec PR-06C

i) majority are 0.6 cm^3 'Farmer-type' chambers
ii) 5 scanning chambers, NO microchambers
iii) A-150 chambers explicitly excluded
iv) Parallel-plate chambers also excluded

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B.4 Polarizing voltage

Based on results in the literature we can state the following:

- Not all chambers follow standard 'Boag' theory
- Manufacturers' statements on voltage limits need verifying (at least for chamber types, if not individual chambers)
- Going to a higher polarizing voltage can lead to a larger uncertainty in the measurement
- Recombination can be a function of the sign of the charge collected
- and the chamber is normal, these matching data should be accurate to within 0.5%. It is the responsibility of the user to confirm this by comparing the results to those of a calibrated ... chambers for which data are given in the protocol

B.5 Measurement of P_{pol}

The polarity correction should be measured for any new chamber and beam combination. It doesn't take very long.

The measurement of P_{pol} is a very simple QA check of the chamber/electrometer system:

i) it confirms that the polarizing voltage is applied correctly between the chamber's electrodes,

ii) chamber-to-chamber variations in P_{pol} tend to be small – any deviation from published values may indicate non-standard behaviour

iii) any change in P_{pol} with time indicates a possible change in chamber response.

B.7 Use of small-volume chambers

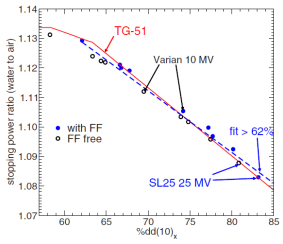
- Very small chambers (volumes < 0.05 cm^3) are not recommended for reference dosimetry. *They do not meet the specification for a reference dosimeter.*
- Issues include: anomalous recombination behaviour, large polarity effect, long settling times, leakage, cable currents.
- These can also impact relative dosimetry measurements (such as measurement of depth-dose curves or beam profiles)
- Careful characterization of such chambers is recommended before use in any situation.

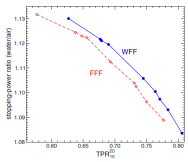
and the chamber is normal, these matching data should be accurate to within 0.5%. It is the responsibility of the user to confirm this by comparing the results to those of a calibrated ... chambers for which data are given in the protocol

B.9 Flattening-filter-free linacs

A. Beam quality specification

$TPR_{20,10}$ and $\%dd(10)_x$ are both valid in heavily filtered beams
but $\%dd(10)_x$ provides greater consistency in assignment of k_Q factors across varied MV beams (low-Z targets, flattening free linacs, etc).





Consistent with k_Q measurements from lightly filtered linacs

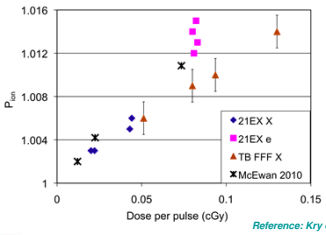
Reference: Xiong & Rogers (Med. Phys., 2008)

B.9 Flattening-filter-free linacs

B. Measurement issues

***Dose averaging** – dose profile is significantly peaked, therefore averaging of a large volume ion chamber can be significant*

***Ion recombination** - dose per pulse is larger than for standard linacs*



Make sure you know how your linac operates

Reference: Kry et al (JACMP, 2012)

Part 2 – electron dosimetry

- Same basic equation is used for electrons as for photons:

$$D_{w,Q} = N_{D,w}^{^{60}Co} k_Q M_{ion}$$

- k_Q is split into 3 components:

$$k_Q = P_{gr} k_{ecal} k'_{R_{50}}$$

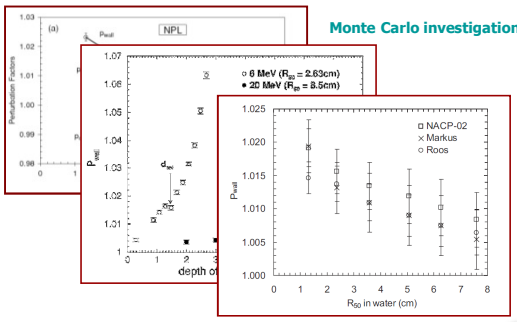
- P_{gr} corrects for gradient effects (thimble chambers only)
- k_{ecal} converts from Co-60 to a high-energy electron beam
- k'_{R50} gives relative energy dependence in electron beams

Part 2 – work required

$$k_Q = P_{gr} k_{ecal} k'_{R_{50}}$$

- P_{gr} - need to revisit in light of new effective point of measurement data for photon beams.
- k_{ecal} – improved value available in literature for NACP-02 chamber, new values required for new chamber types (Exradin A10, IBA PPC-05, PTW34045).
- k'_{R50} – TG-51 assumes that well-guarded parallel-plate chambers have a unity perturbation correction. Multiple publications now show this is not the case – new data required.

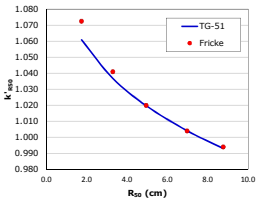
1. Ion-chamber perturbation corrections



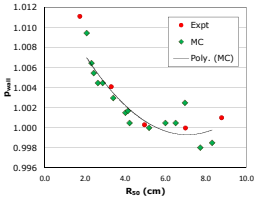
Monte Carlo investigations

References: Verhaegen et al (PMB, 2006), Buckley and Rogers (Med. Phys., 2006), Araki (Med. Phys., 2008)

Measurement of k'_{R50}



Reference: Cojocaru et al, (IAEA Symposium, 2010)



MC data from: Zink and Wulff (PMB, 2010)

Early days – more work required to develop electron beam primary standards and evaluate suitable reference chambers

Conclusions

- There is still interesting work to be done in the field of reference dosimetry
- TG-51 is looking (pretty) good as it moves into a second decade
- Some changes are required – both photons and electrons
- Keep an eye out for published Addenda