Slide 1

# TG-61: A Dosimetry Protocol for Kilovoltage X-ray Beams

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Slide 2

## AAPM TG-61 Report

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Slide 3

## Outline

- Kilovoltage x-ray dosimetry- a review
- Dosimeters and calibration procedures
- Formalisms for kV x-ray dose determination
- AAPM recommendations - TG-61 Report

Slide 4

## The physics of kV x-ray dosimetry

- Very short electron ranges (< 0.5 mm water)
- Large scatter contributions and SSD, field size, beam quality dependent
- Bragg-Gray cavity conditions very difficult to fulfil - even for air-fill ion chambers
- Kerma = dose (also $K_{col}$ = K as negl. Brem.)
- Ion chambers calibrated as "exposure meters" and used as "photon detectors"

Slide 5

## Detectors for kV x-ray beams

- Air-filled ion chambers are recommended for absolute dose measurements

- Diode, film, diamond detectors for relative measurements

Slide 6

## Kilovoltage x-ray dosimetry- a review

- ICRU Report 23 (1973) significant changes made
  40-150 kV in-air method, >150 kV in-phantom
- NCRP Report 69 (1981) only protocol for N. Ame.
  10 kV and above, in-air method, no BSF given
- IAEA Report 277 (1987) significant changes made
  10-100 kV in-air method, >100 kV in-phantom

Slide 7

## Kilovoltage x-ray dosimetry- a review

- IPEMB Code of Practice (1996) with three ranges
  Very low- (< 1mmAl) in-phantom, low- (1-8mmAl) in-air, medium-energy (>0.5mmCu) in-phantom
- NCS Code of Practice (1997) two energy ranges
  50 - 100 kV in-air method, 100 - 300 kV in-phantom
- IAEA Code of Practice (2000) - new recommendations
  Absorbed dose based, consistent with other beams

Slide 8

## Kilovoltage x-ray dosimetry

- For low-energy (40 - 150 kV, 8mm Al HVL) x-rays - the backscatter method
- For medium-energy (100 - 300 kV, 4mm Cu HVL) x-rays - the in-phantom Method
  (except for NCRP Report 69)

Slide 9

## Why (not) backscatter method?

Widely used in practice but…

- BS factor mainly from calculations
- BS factor varies with SSD, field size, and energy (beam quality)
- Measured quantity is kerma (not dose)
- High uncertainty in PDD near the surface
- Not well verified for medium-energy beams

Slide 10

## What’s New in AAPM TG-61?

- Use both the in-air and in-phantom methods for tube potentials 100 - 300 kV
- More complete data (for water, tissue & bone)
- Recommendations for relative measurements
- Recommendations for QA and consistency check

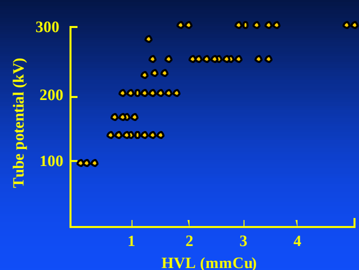
Slide 11

## Beam quality specification

- Use a “narrow beam geometry”

- Half-Value Layer expressed in mm Ai or Cu
  - for 40-150 kV x-rays: use mmAl
  - for 100 - 300 kV x-rays: use mmCu

Slide 12



Slide 13

## Beam quality specification

- Use both tube potential and HVL to specify beam quality for chamber calibration
- Use HVL to specify beam quality for determination of chamber correction and conversion factors

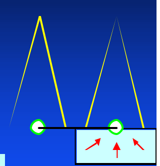
Slide 14

## Formalism for kV x-ray dosimetry

- The backscatter method

$$N_K = K_c / M_c$$

$$D_w = MN_K (\mu_{en}/\rho)^{w}_{air} P_{stem,air} B_w$$



Slide 15

## Derivation for the In-Air Method

- Determine the air kerma at a point in air in absence of the chamber $K^{in-air}_{air} = MN_K P_{stem,air}$
- Convert air kerma to water kerma by $K^{in-air}_{w} = K^{in-air}_{air} (\mu_{en}/\rho)^{w}_{air}$
- Derive water kerma on the surface using a backscatter factor $K_w = K^{in-air}_{w} B_w$
- Derive absorbed dose to water from water kerma assuming charged particle equilibrium $D_w = K_w$ CPE exists

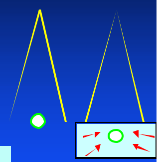
Slide 16

## Formalism for kV x-ray dosimetry

- The in-phantom method

$$N_K = K_c / M_c$$

$$D_w = M N_K (\mu_{en}/\rho)^{w}_{air} P_{sheath} P_{Q,cham}$$



Slide 17

## Derivation for the In-Phantom Method

- Determine the air kerma at a point in water in absence of the chamber $K_{air}^{in-water} = M N_K P_{Qcham} P_{sheath}$
- Convert air kerma to water kerma by $K_w = K_{air}^{in-water} (\mu_{en}/\rho)^{w}_{air}$
- Derive absorbed dose to water from water kerma assuming charged particle equilibrium

$D_w = K_w$ CPE exists

Slide 18

## Consistency between the in-air and in-phantom methods

- Select a method based on point of interest
- Check consistency only if PDD can be measured accurately
- Experimental studies indicated consistent results (about 1%) using both methods at 100 and 300 kV

Slide 19

## Guidelines for dosimetry in other phantom materials

- Determine the surface dose for other phantom materials from

$$D_{\mathrm{med},z=0} = C_{\mathrm{w}}^{\mathrm{med}} D_{\mathrm{w},z=0}$$

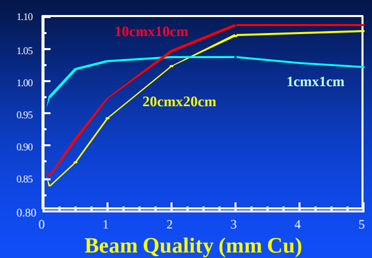
- where

$$C_{\mathrm{w}}^{\mathrm{med}} = \frac{B_{\mathrm{med}}}{B_{\mathrm{w}}} \left[ (m_{\mathrm{en}} / r)_{\mathrm{w}}^{\mathrm{med}} \right]_{\mathrm{air}}$$

- The backscatter factor ratios are significant for bone to water but close to 1.0 for soft tissues.

Slide 20

## Ratio of Backscatter Factors, Bone to Water

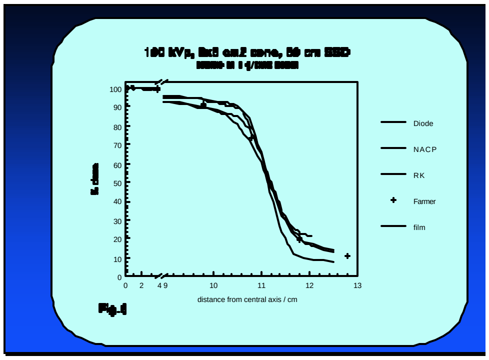



Slide 21

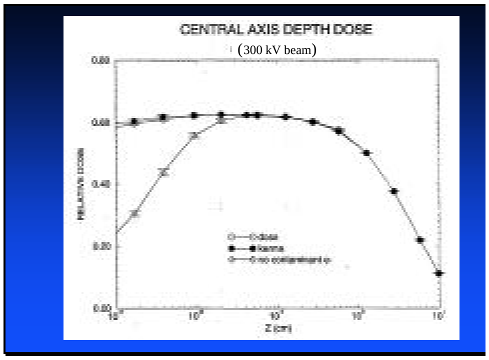
## Relative dosimetry measurement

- Large uncertainty in PDD measurements
- Large uncertainty in profile measurements
- Effect of electron contamination
- Choice of detectors
- Choice of phantom materials

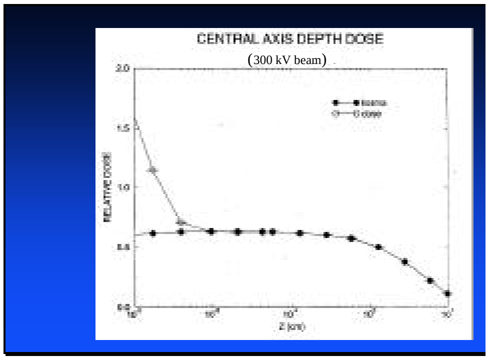
Slide 22




Slide 23




Slide 24



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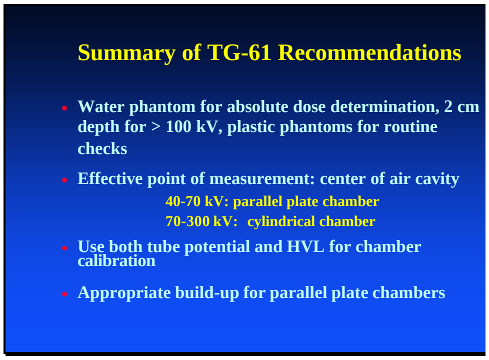
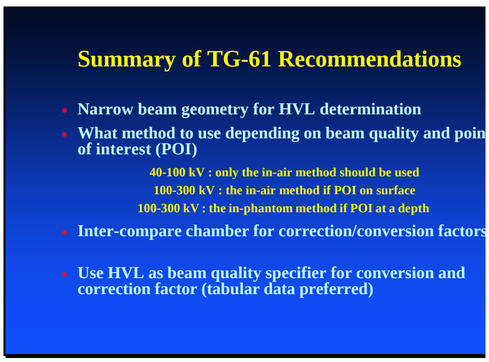



Slide 26




Slide 27