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

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AAPM TG-61 Report

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Outline

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

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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 $K_{\text{air}} = K$ as negl. Brem.)
- Ion chambers calibrated as “exposure meters” and used as “photon detectors”

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Detectors for kV x-ray beams

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



- Diode, film, diamond detectors for relative measurements

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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

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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

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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)

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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

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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

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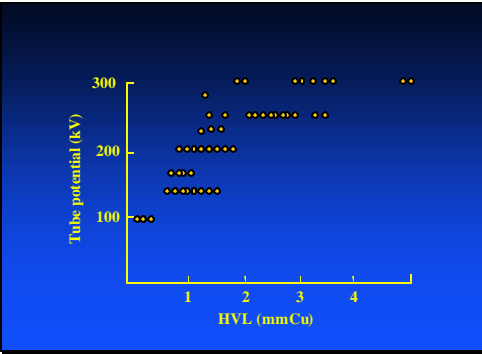
Beam quality specification

- Use a "narrow beam geometry"



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

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Beam quality specification

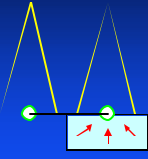
- Use both tube potential and HVL to specify beam quality for chamber calibration
- Use HVL to specify beam quality for determination of chamber correction and conversion factors

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Formalism for kV x-ray dosimetry

- The backscatter method

$$N_K = K_c / M_c$$



$$D_w = M N_K (m_{en} / \rho)_{air}^w P_{stem,air} B_w$$

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Derivation for the In-Air Method

- Determine the air kerma at a point in air in absence of the chamber

$$K_{air}^{vac} = M N_K P_{correction}$$
- Convert air kerma to water kerma by

$$K_{air}^{vac} = K_{air}^{vac} (m_{en} / \rho)_{air}^w / (m_{en} / \rho)_{air}^w$$
- Derive water kerma on the surface using a backscatter factor

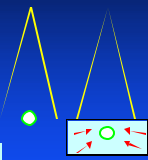
$$K_c = K_{air}^{vac} B_r$$
- Derive absorbed dose to water from water kerma assuming charged particle equilibrium, CPE exists

$$D_w = K_c$$

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Formalism for kV x-ray dosimetry

- The in-phantom method

$$N_K = K_c / M_c$$
$$D_w = MN_K (m_{en} / \rho)^w_{air} P_{sheath} P_{Q, cham}$$


The diagram shows an x-ray source (yellow dot) emitting a beam (yellow lines) through a phantom (blue area) to a detector (green circle). The detector is surrounded by a red dashed line, indicating the measurement volume.

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Derivation for the In-Phantom Method

- Determine the air kerma at a point in water in absence of the chamber
 $K_{air}^{w, in} = MN_K P_{Q, cham} P_{sheath}$
- Convert air kerma to water kerma by
 $K_w = K_{air}^{w, in} (m_{en} / \rho)^w_{air}$
- Derive absorbed dose to water from water kerma assuming charged particle equilibrium
 $D_w = K_w$ CPE exists

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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

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Guidelines for dosimetry in other phantom materials

- Determine the surface dose for other phantom materials from

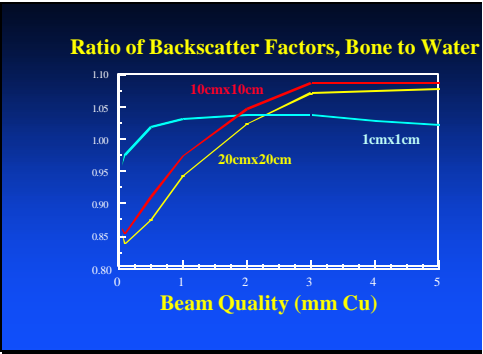
$$D_{\text{med},z=0} = C_w^{\text{med}} D_{w,z=0}$$

- where

$$C_w^{\text{med}} = \frac{B_{\text{med}}}{B_w} \left[\frac{m_{\text{en}}}{\rho} \right]_{\text{air}}^{\text{med}}$$

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

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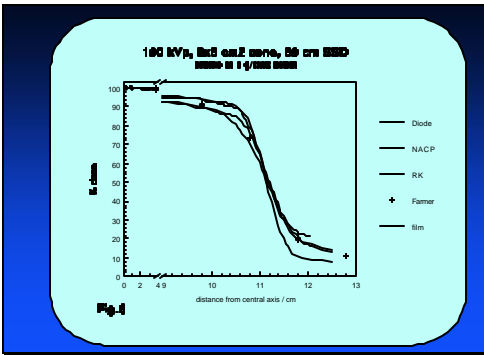


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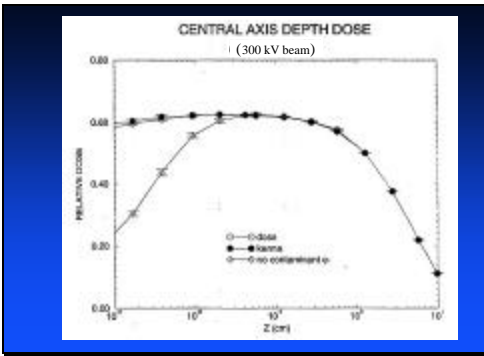
Relative dosimetry measurement

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

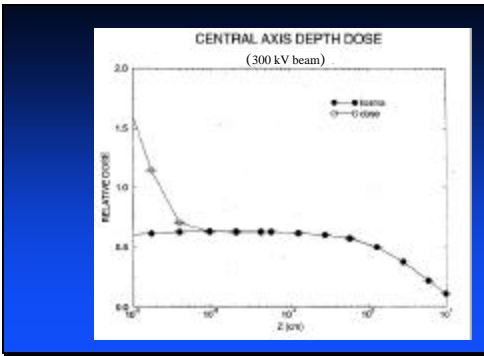
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Summary of TG-61 Recommendations

- Water phantom for absolute dose determination, 2 cm depth for > 100 kV, plastic phantoms for routine checks
- Effective point of measurement: center of air cavity
 - 40-70 kV: parallel plate chamber
 - 70-300 kV: cylindrical chamber
- Use both tube potential and HVL for chamber calibration
- Appropriate build-up for parallel plate chambers

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Summary of TG-61 Recommendations

- Narrow beam geometry for HVL determination
- What method to use depending on beam quality and point of interest (POI)
 - 40-100 kV : only the in-air method should be used
 - 100-300 kV : the in-air method if POI on surface
 - 100-300 kV : the in-phantom method if POI at a depth
- Inter-compare chamber for correction/conversion factors
- Use HVL as beam quality specifier for conversion and correction factor (tabular data preferred)

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Conclusions

- Exposure/kerma based dosimetry procedures
- Backscatter method for both low- and medium-energy x-ray beams
- Complete data set available for μ_{en}/ρ , B , $P_{Q, cham}$ and P_{sleeve}
- Consistent results using both formalisms
