Practical Implementation of TG-61:

II. Guidelines for clinical implementation of TG-61

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TG-61 deals with:

- Calibration of absolute output of orthovoltage x-ray units in terms of D_w
- Relative dosimetry of orthovoltage beams
- Clinical issues
  - electron contamination
  - dose in biological tissues

This part of the refresher course:

- Aspects and pitfalls of absolute output calibration
- Peculiarities in relative dosimetry of kilovoltage beams
- Other clinical issues

Absolute calibration: Summary of recommendations

- tube potential < 100 kV
  - in-air method mandatory
- tube potential ≥ 100 kV
  - in-phantom method allowed
- choice for medium energies to be made based on the location of the point of interest (target volume)

Chambers

- Chambers:
  - low energy
    - tube potential < 70 kV: soft x-ray parallel plate chambers
    - tube potential ≥ 70 kV: cylindrical chambers with flat energy response
  - medium energy
    - cylindrical chambers with flat energy response

Phantoms

- no phantom
  - for in-air method
- water phantom
  - for in-phantom reference dosimetry
  - for relative dosimetry
- plastic phantoms for stability checks

I. Absolute calibration:

a. In-air method

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Absolute Calibration: In-air method

$$D_W(0\text{ cm}) = M N_K P_{stem,air} \left[\left(\frac{\bar{\mu}_{en}}{\rho} \right)_{air}^{w} \right]_{air} B_W$$

M: "corrected" chamber reading

N_K: air-kerma calibration factor

$P_{stem,air}$: stem correction factor free-in-air

$\left[\left(\frac{\bar{\mu}_{en}}{\rho} \right)_{air}^{w} \right]_{air}$ mass-energy absorption coefficient ratio water to air, free-in-air

B_w: back-scatter factor

In-air method: 2 conceptual steps

- Step 1: measure air-kerma in clinical beam
  - get and interpolate N_K from a standards dosimetry laboratory (ADCL's, NIST, NRCC)
  - establish $P_{stem,air}$

$$K_{air}(\text{clinical beam}) = M N_K P_{stem,air}$$

In-air method: 2 conceptual steps

- Step 2: look-up conversion factor and backscatter factor

$$D_w \cong K_w = K_{w,air} B_w = K_{air} \left[\left(\frac{\bar{\mu}_{en}}{\rho} \right)_{air}^{w} \right]_{air} B_w$$

STEP 1:

Getting a calibration factor from standards lab & Evaluating $P_{stem,air}$

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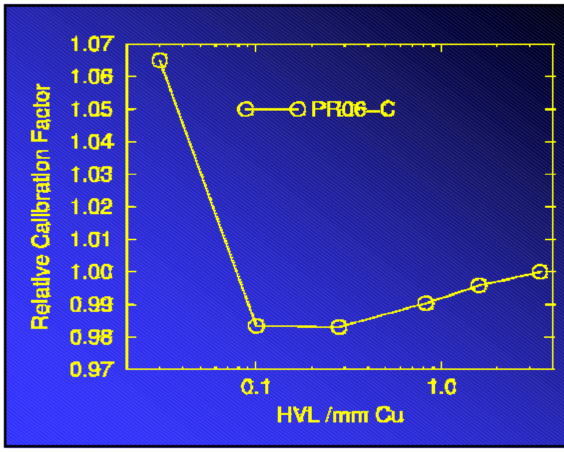
Get N_K from standards lab

- calibration in terms of air-kerma (for both in-air and in-phantom method):

  beam quality specification is in terms of both *HVL* and tube potential

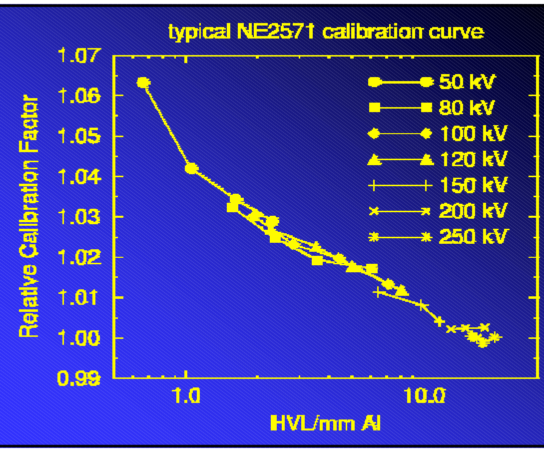
NIST calibration qualities disseminated by ADCL's

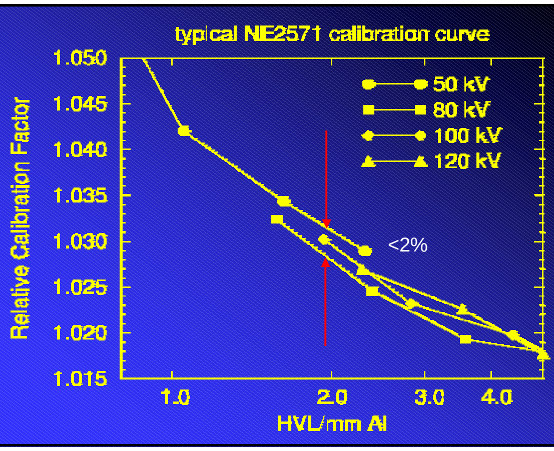
Beam Code	First HVL (mm Al)	First HVL (mm Cu)	Hom. Coeff. (Al)
L40	0.50		59
L80	1.83		57
M40	0.73		69
M80	2.97		67
M100	5.02		73
M150	10.2	0.67	87
M300	22.0	5.3	100



Energy dependence of chamber calibration factor?

"... calibration factors should not vary significantly between two calibration points so that the estimated uncertainty in the calibration factor for a clinical beam between the two calibration points is within 2%."



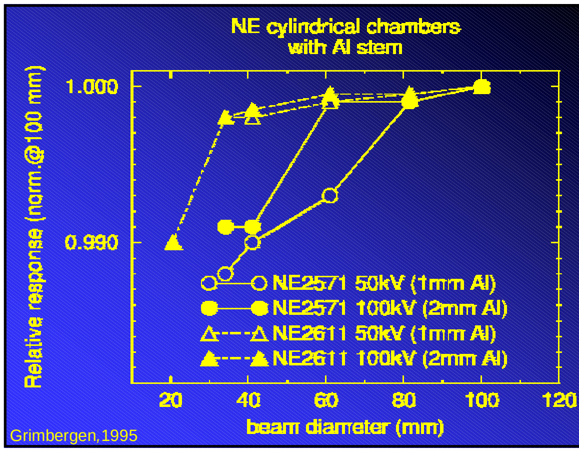


Energy dependence: in practical terms

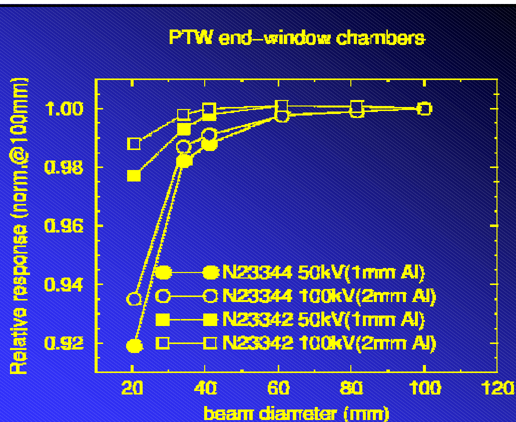
- chamber response should be known approximately, *e.g.,* from manufacturer
- calibration for at least two radiation qualities that bracket the radiation quality used in the clinic
- N_K(x-rays)/N_K(^{60}Co) should be as expected

In-air method: evaluate $P_{stem,air}$

- for cylindrical chambers, stem effect in-air is usually less than 1% so $P_{stem,air}$<1%
- stem scatter for "large body" end-window or superficial therapy chambers can be appreciable and should be checked



Grimbergen,1995



Grimbergen,1995

Measuring $P_{stem,air}$

- comparison to chamber with known $P_{stem,air}$
  - M chamber reading, M_{ref} reference chamber reading
  - f_c field size at calibration lab; f_u field size in clinical beam

$$P_{stem,air}(f_u) = \frac{M(f_c)\,M_{ref}(f_u)}{M(f_u)\,M_{ref}(f_c)} P_{stem,air}(f_c)$$

STEP 2:

Data on

mass-energy absorption coefficients
&
Backscatter factors

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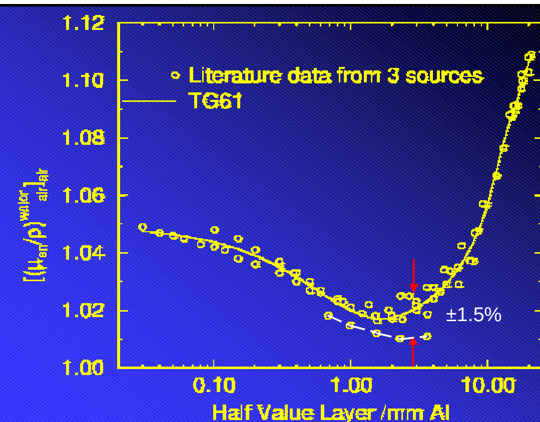
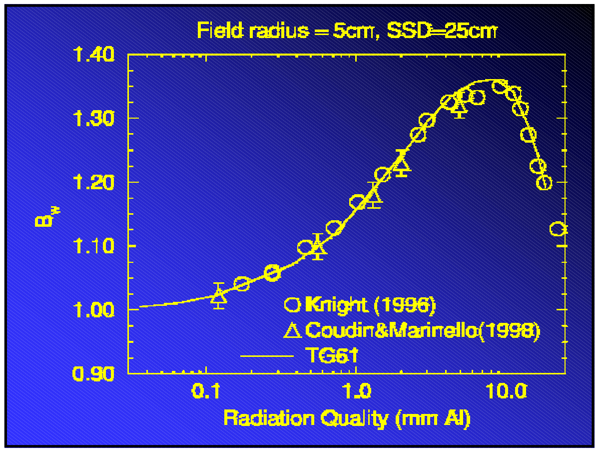


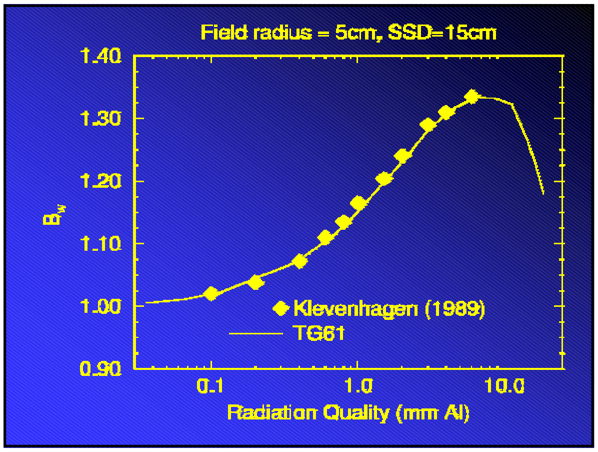
Backscatter factors

- B_w is a kerma based quantity:

$$B_W = \frac{K_{w,phantom}}{K_{w,free\text{-}air}}$$

- Based on Monte Carlo calculations
  - TG61 adopted data sets from Grosswendt (1990, 1993)
- "Surface kerma" is very difficult to measure with chambers
  - electron contamination
  - chamber response issues





Clinical issues of in-air method

- strain on accurate knowledge of energy dependence of chamber response
- clinical relevance of electron contamination at the surface
- validity of backscatter factors for small cones

In-air method:

Uncertainty at the reference point

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Overall uncertainty: In-air method

Type of quantity or procedure	Uncertainty
N_K from standards lab	0.7%
Effect of beam-quality difference	2.0%
Backscatter factor B_w	1.5%
$P_{stem,air}$	1.0%
$\left(\frac{\bar{\mu}_{en}}{\rho}\right)^{w}_{air}$	1.5%
Free-air measurement in user's beam	1.5%
Combined $D_{w,z=0}$	3.5%

I. Absolute Calibration:

b. In-phantom method

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Summary: In-phantom method

$$D_w(2\text{ cm}) = M N_K P_{sheath} P_{Q,cham} \left(\frac{\bar{\mu}_{en}}{\rho}\right)_{air}^{w}$$

M: "corrected" in-phantom chamber reading

N_K: air-kerma calibration factor

P_{sheath}: sheath correction factor

$P_{Q,cham}$: chamber correction factor

$\left(\frac{\bar{\mu}_{en}}{\rho}\right)_{air}^{w}$ mass-energy absorption coefficient ratio water to air, in-phantom

Background: In-phantom method

- Step 1: measure air kerma in water:
  - get and interpolate N_K from a standards laboratory (see: in-air method)
  - perform in-phantom measurement M (2 cm)

$$K'_{air}(w) = M N_K$$

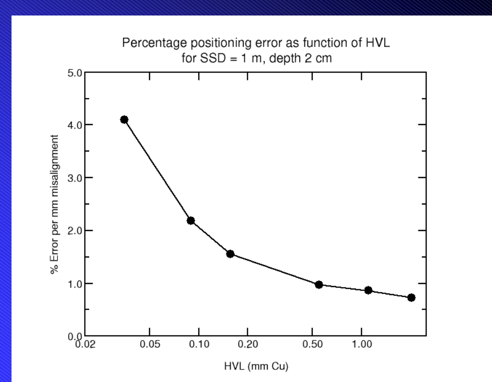
Background: In-phantom method

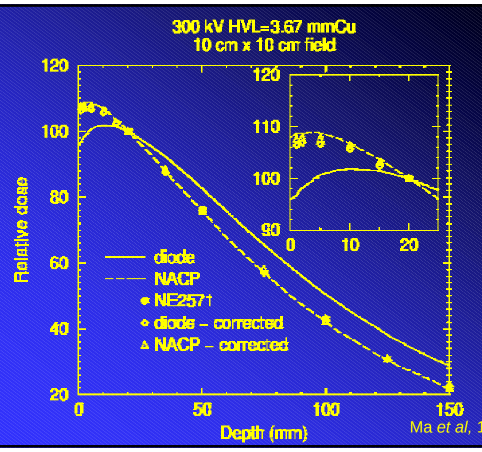
- Step 2: lookup conversion factor, chamber correction factor, sheath correction factor

$$D_w \cong K_w(w) = \underbrace{K'_{air}(w) P_{Q,cham} P_{sheath}}_{K_{air}(w)} \left(\frac{\bar{\mu}_{en}}{\rho}\right)_{air}^{w}$$

Clinical issues of in-phantom method

- positioning uncertainties
- strain on accuracy of PDD if point of interest is more shallow than the calibration depth of 2 cm (i.e., errors get "blown up")





Ma *et al*, 1998

In-phantom method:

Uncertainty at the reference point

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In-phantom method

Type of quantity or procedure	Uncertainty
N_K from standards lab	0.7%
Effect of beam-quality difference	2.0%
Chamber correction factor $P_{Q,cham}$	1.5%
Sleeve correction factor P_{sheath}	0.5%
$\left[\left(\frac{\mu_{en}}{\rho}\right)_{air}^{w}\right]_{water}$	1.5%
In-water measurement in user's beam	2.0%
Combined $D_{w,z=2cm}$	3.6%

II. Relative Dosimetry

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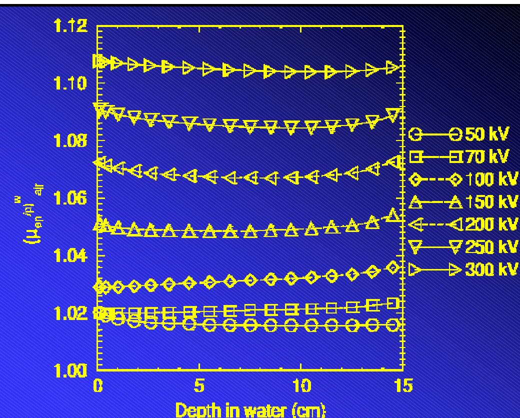
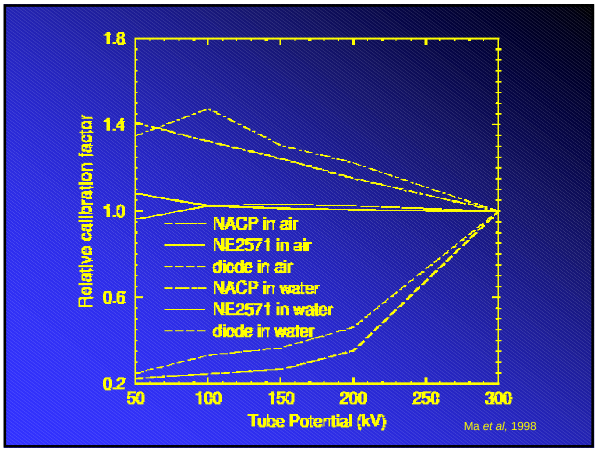
Relative dosimetry - what do we require

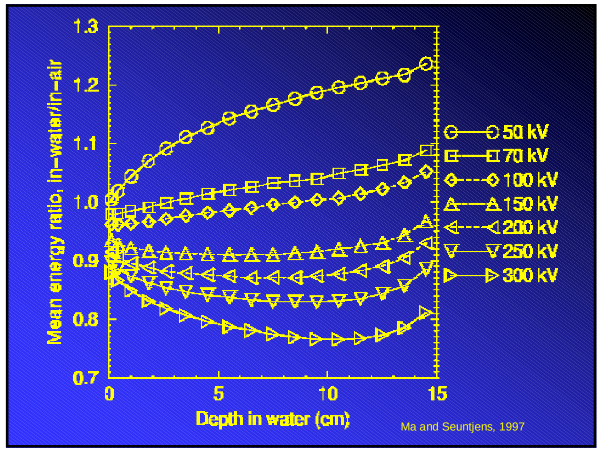
- which detectors can one use to measure PDD and profiles ?
  - spatial resolution requirements
  - energy dependence requirements

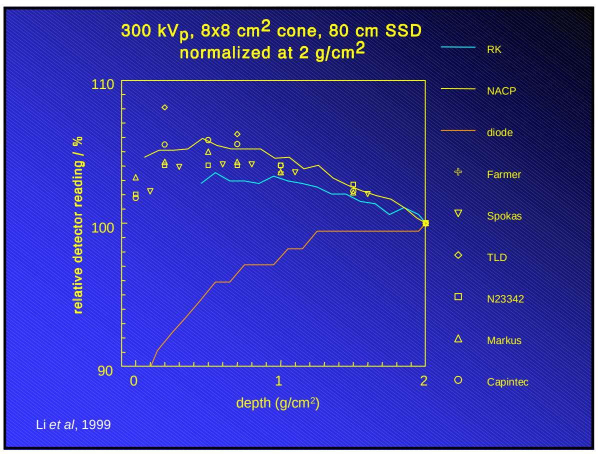
$$D_W(z) = N_K M(z)\left[P_{Q,cham}P_{sheath}\left[\left(\frac{\mu_{en}}{\rho}\right)_{air}^{w}\right]_{w}\right](z)$$

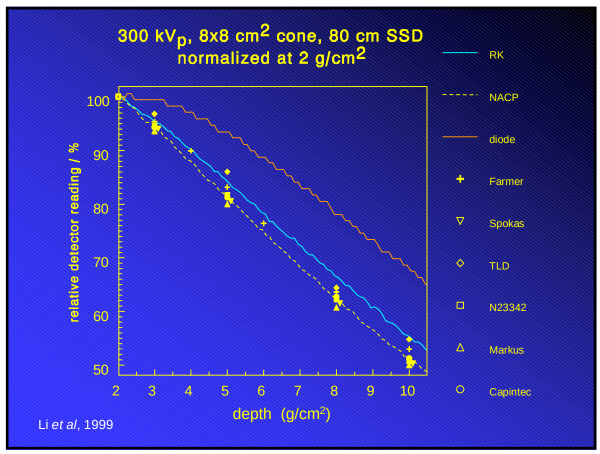


Ma and Seuntjens, 1997







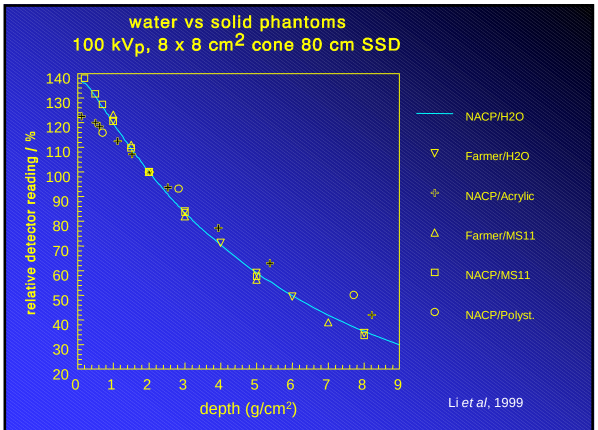


Dosimeters for relative dosimetry

Acceptable dosimeters	Unacceptable dosimeters
At depth: cylindrical chambers with favourable energy response	General: chambers with bad in-phantom response characteristics
At surface: plane parallel electron chambers (tested: NACP, Markus)	Chambers with high-Z components in or near detection volume
radiochromic film, diamond detectors, liquid ionization chambers	Diodes, silver-based film, TLD?

Phantoms

- plastic phantom materials useful for QA of output
- NOT for absolute calibrations unless investigated



Uncertainties in the dose at other points in water

Type of quantity or procedure	Uncertainty
Combined $D_{w,z=2cm}$ (in-phantom)	3.6%
Combined $D_{w,z=0cm}$ (in-air)	3.5%
Determination of dose at other points in water	3.0%
Overall	4.7%

Other clinical issues

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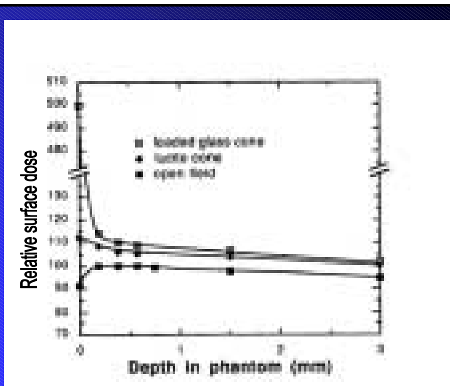
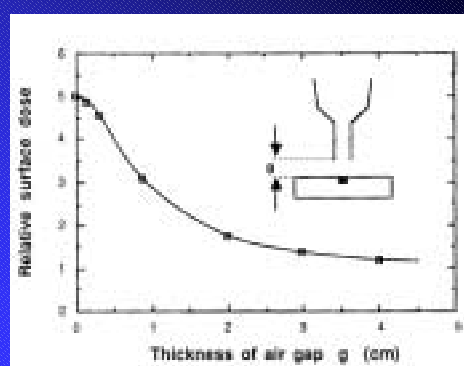
Surface dose and electron contamination

- TG-61 is a kerma-based protocol, i.e, surface dose cannot be derived from an air-kerma protocol
- Surface dose, should be assessed using thin window plane parallel chambers and dealt with if clinically important



Podgorsak *et al*, 1990



Podgorsak *et al*, 1990

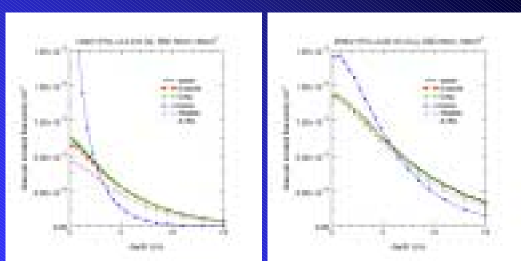
Dose in biological tissues

- TG-61 provides a method to calculate dose at the surface of tissue phantoms

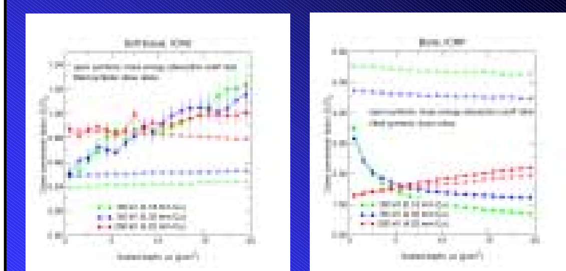
$$C_w^{med} = \frac{B_{med}}{B_w}\left[\left(\frac{\bar{\mu}_{en}}{\rho}\right)_w^{med}\right]_{air}$$

Dose in biological tissues

- for soft tissues the ratio of the backscatter factors is ignored; for compact bone, a table is provided
- no recommendations on how to calculate dose at depth in the patient



Seuntjens and Ma, 1999



Seuntjens and Ma, 1999

Conclusions

- TG-61 is an air-kerma based protocol recommending
  - in-air method (low and medium energy if point of interest is at the surface)
  - in-phantom method (medium energy if point of interest is at a depth in-phantom)
- We discussed:
  - calibration issues
  - relative dosimetry
  - some clinical issues