PRACTICAL ASPECTS OF COMMISSIONING AND CALIBRATION OF CLINICAL ORTHOVOLTAGE UNITS

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Outline

- *Kilovoltage unit definition*
- *Calibration and commissioning of an orthovoltage unit*
- *Clinical applications*
- *Quality assurance*

Low energy photon radiotherapy

(Based on F.M. Khan, The physics of radiation therapy, second Edition)

- Grenz-ray therapy
  - energy < 20 kVp
- Contact therapy
  - 40-50 kVp
  - SSD < 2 cm
  - ~ 2 mA
- Superficial therapy
  - 50-150 kVp
  - SSD = 15-20 cm
  - ~ 5-8 mA
- Orthovoltage therapy ("Deep" therapy)
  - 150-500 kVp
  - SSD ~ 50 cm
  - 10-20 mA

Superficial vs. Orthovoltage

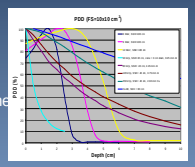
	Superficial	Orthovoltage
BJR Supplement 25 (1996)	HVL 0.01 mm -8.0 mm Al (approx. 6 -150 KV)	HVL 0.5 mm – 4.0 mm Cu
IAEA TRS-398 (2000)	≤ HVL 3.0 mm Al (100 kV)	≥ HVL 2.0 mm Al (80 kV)
AAPM TG-61 (2001)	40 kV - 100 kV	100 kV – 300 kV

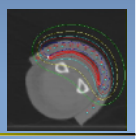
Treatment applications

- Skin cancer
  - Melanoma
  - Basal cell carcinoma (BCC)
  - Squamous cell carcinoma (SCC)
- Other skin lesions
  - Keloid treatment

Kilovoltage clinical application

- Low energy photons
  - Advantages
    - Sharp penumbra
    - Small lesions
    - Less complexity of machine and treatme
    - Easy setup
  - Disadvantages
    - Penetrating beam
    - Higher dose to the bone
- Electron beam advantages:
  - Sharp falloff of the PDD
  - Better cosmetic outcome
  - Bone "sparing"
- Brachytherapy advantages:
  - Better outcomes for some selected sites





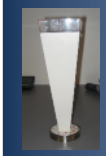
Calibration and commissioning of an orthovoltage unit

Gulmay D3225 Orthovoltage Unit

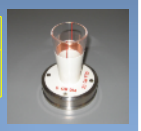
- *Gulmay Medical Limited, Chertsey, Surrey, UK*
  - Floor mounted tube stand and treatment table
  - Comet MXR321 metal Ceramic x-ray tube assembly
  - 9 treatment filters and 1 warm up filter
  - 6 square applicators (SSD = 50 cm)
  - 4 circular applicators (SSD = 20 cm)
- *X-ray beam specification*
  - X-ray tube output limits:
    - 20-220 kV, 0-20 mA, 400-3000 W
    - kVp at the JGH : 80, 120, 180, and 220 kVp
- *Tube*
  - Focal spot : ~7.5 mm
  - Target: Tungsten
  - Inherent filter: 0.8 ± 0.1 mm Be
  - Tube power max : 3000 W
  - Field coverage total: 40º
  - Anode angle: 30º
  - Weight: 11 Kg

Gulmay D3225 Orthovoltage Unit

Filters (9 + 1)



Square (cm x cm) SSD = 50 cm	4x4	6x6	8x8	10x10	15x15	20x20
Circular diameter (cm), SSD = 20 cm	3	4	5	10		



Calibration

- Protocol:
  - The American Association of Medical Physicists Task Group 61 (AAPM TG-61)
- Requirements
  - Ionization chamber with an air kerma free in air calibration coefficient N_k traceable to national standards
  - N_K can be calculated from the exposure calibration coefficient N_X :

$$N_K = N_X\,(W/e)_{air} / (1-g)$$

Beam quality

- Beam quality depends on:
  - Tube potential
  - Target material and angle
  - Window material and thickness
  - Monitor chamber material and thickness
  - Filtration material and thickness
  - Shape of collimator
  - Source-chamber distance

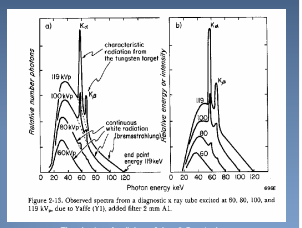


Figure 2-13. Observed spectra from a diagnostic x ray tube excited at 80, 60, 100, and 119 kV_p, due to Yaffe (91), added filter 2 mm Al.

The physics of radiology, Johns & Cunningham

Beam quality specifier

- Standards lab: HVL_1 and kVp for determination of N_k
- Clinical unit: HVL_1 for determination other parameters in the TG-61 formalism

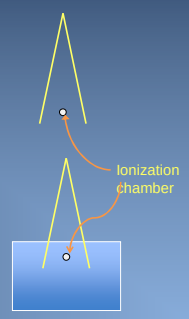
Formalism: TG-61

- *In air method:*
  - *Measurement performed in air*
  - 40 kV ≤ Tube potential ≤ 300 kV

$$D_{w,x=0} = MN_k B_w P_{wall,air} \left[\left(\frac{\bar{\mu}}{\rho}\right)_{air}^{w}\right]_{air}$$

- *In phantom method:*
  - *Measurement performed in Water*
  - *Size: At least 30 × 30 × 30 cm³*
  - 100 kV < Tube potential ≤ 300 kV

$$D_{w,x=z} = MN_k P_{cl,phant} P_{wall} \left[\left(\frac{\bar{\mu}}{\rho}\right)_{air}^{w}\right]_{w}$$



Dosimeters

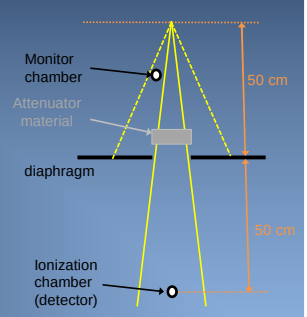
- Parallel-plate chambers:
  - below 70 kV
- Cylindrical chambers
  - For 70 kV – 300 kV
- Appropriate buildup should be used to eliminate the effect of contaminating electrons

Determination of HVL

- 1st HVL: thickness of a specified attenuator that reduces the air-kerma rate in a narrow beam to ½ its original value.
  - Measurement of the variation with the attenuator thickness of the air-kerma rate at a point in a "scatter free" and narrow beam.
  - Detectors with sufficient build-up should be used to eliminate the effect of contaminating electrons.

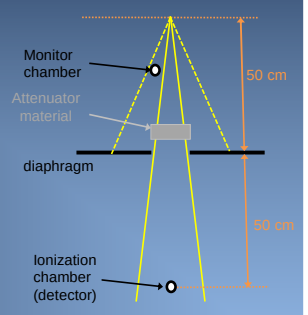
Determination of HVL: TG-61 recommendations

- Diaphragm
  - Beam diameter ≤ 4 cm
  - Thickness must attenuate primary beam to 0.1 %.



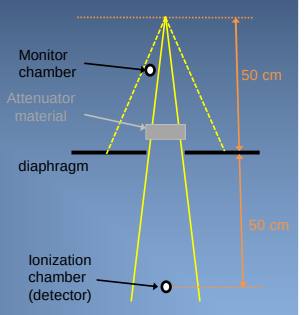
Determination of HVL: TG-61 recommendations

- Monitor chamber
  - Used to correct for kerma rate variations
  - Should not perturb the narrow beam.
  - Should not be affected by the attenuator material

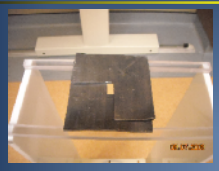


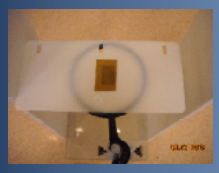
Determination of HVL: TG-61 recommendations

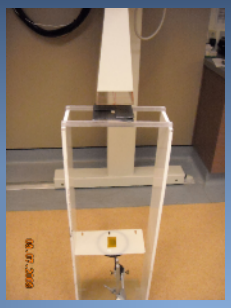
- Attenuator
  - High-purity material (99 %).
  - Thickness measured with an accuracy of 0.05 mm.



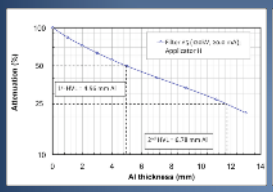
HVL measurement

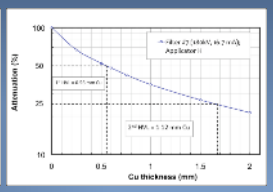






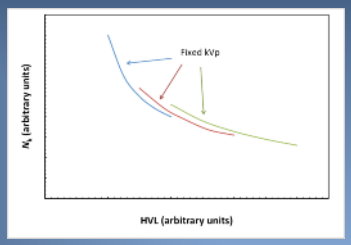
HVL measurement





Determination of N_k for a clinical beam (TG-61 recommendation)

- Use of kVp and HVL
  - *Ideal*: Obtain N_k for the same kVp and HVL beam that matches the user clinical beam
  - *Practical*: Obtain N_k for two beams with the same kVp but two HVLs and interpolate using the HVL for the clinical beam



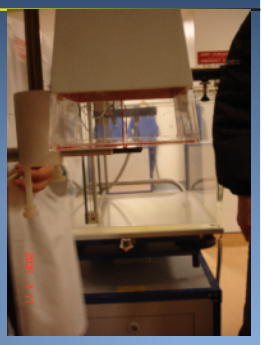
Determination of N_k in the clinic (TG-61 recommendation)

- ADCL's provide calibration coefficients for specific beam qualities that are grouped into:
  - Lightly filtered (*L series*)
  - Medium filtered (*M series*)
  - Heavily filtered (*H series*)
- Interpolation based on HVL may only be performed within the *same* series

	Added Filter				HVL	
Beam Code	Al (mm)	Cu (mm)	Sn (mm)	Pb (mm)	Al (mm)	Cu (mm)
L10	0				0.037	
L15	0				0.059	
L20	0				0.07	
L30	0.3				0.25	
L40	0.53				0.53	
L50	0.71				0.79	
L80	1.45				1.81	
L100	1.98				2.8	
M20	0.27				0.15	
M30	0.5				0.36	
M40	0.85				0.78	
M50	1.07				1.04	
M60	1.51				1.64	0.067
M80	2.56				2.98	0.1
M100	3.16				5	0.3
M120	3.12				8.72	0.3
M150	5.25	0.25			10.1	0.66
M200	4.15	1.17			14.7	1.64
M250	3.25	3.2			18.3	3.4
M300	4.25		4.5		21.4	5.1
H10	0.035				0.031	
H15	0.5				0.16	
H20	1.01				0.36	
H30	4.5				1.3	
H40	4	0.26			2.93	
H50	4			0.1	4.2	0.14
H60	4	0.61			6	0.25
H100	4	5.2			12.4	1.13
H150	4	5	1.95		16.9	2.41
H200	4	6.5	4.16	0.77	19.7	4.1
H250	4	6.5	1.04	2.72	22	5.19
H300	4.1		5	5	23	6.25
S75	3.225				2.81	
S90	4				3.79	0.083

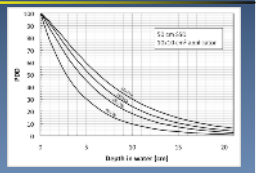
Calibration: Setup

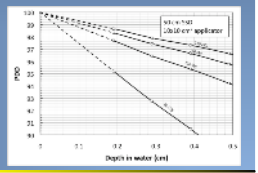
- Chamber: NE 2571 farmer type cylindrical chamber
- Method: in-air
- Output specification point:
  - 0 cm depth in water at the cone end
  - Inverse square factor is required for closed end cones to correct for chamber position



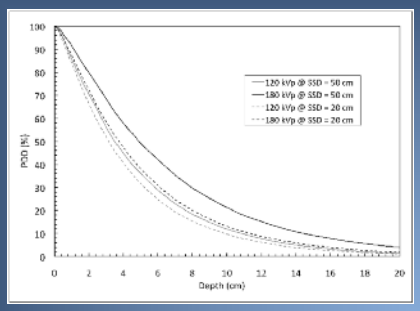
Percentage depth dose

- Measurement medium: water
- Instrument: NACP01 parallel plate chamber
  - Window thickness = 90 mg/cm^2
  - Electrode spacing = 2 mm
  - Effective point of measurement = 1.9 mm

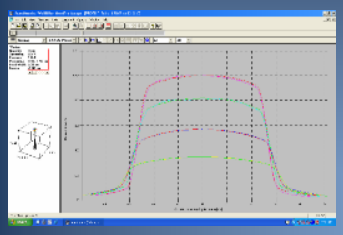


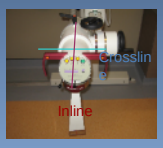


PDD vs. SSD



Beam profiles: Inline and crossline





Back scatter factors

Gulmay Orthovoltage Unit

BACKSCATTER FACTORS

Field Size (cm x cm)	SSD (cm)	Station			
		80 kVp	120 kVp	180 kVp	220 kVp
		2,26 mm Al	4,91 mm Al	0,55 mm Cu	2,17 mm Cu
2 x 2	50	1,119	1,132	1,120	1,077
3 x 3	50	1,155	1,181	1,169	1,111
4 x 4	50	1,182	1,221	1,215	1,142
5 x 5	50	1,203	1,253	1,253	1,170
6 x 6	50	1,217	1,277	1,283	1,193
7 x 7	50	1,232	1,302	1,313	1,217
8 x 8	50	1,246	1,326	1,343	1,241
9 x 9	50	1,261	1,351	1,374	1,265
10 x 10	50	1,266	1,364	1,391	1,281
12 x 12	50	1,278	1,389	1,425	1,312
14 x 14	50	1,287	1,412	1,456	1,341
16 x 16	50	1,292	1,426	1,477	1,360
18 x 18	50	1,296	1,440	1,499	1,380
20 x 20	50	1,301	1,454	1,520	1,399
2 cm diam.	20	1,109	1,118	1,109	1,071
3 cm diam.	20	1,143	1,165	1,154	1,103
4 cm diam.	20	1,167	1,199	1,192	1,130
5 cm diam.	20	1,191	1,233	1,231	1,156
10 cm diam.	20	1,250	1,332	1,351	1,250

Dose to tissue

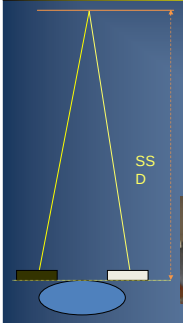
Gulmay Orthovoltage

Conversion factors from Dose-to-water to Dose-to-tissue

	Station			
	80 kVp	120 kVp	180 kVp	220 kVp
	2,26 mm Al	4,91 mm Al	0,55 mm Cu	2,17 mm Cu
ICRU 4- element soft tissue	0.931	0.943	0.958	0.982
ICRU striated muscle	1.032	1.028	1.019	1.000
ICRP lung	1.046	1.039	1.028	1.002
ICRP Skin	0.917	0.934	0.955	0.981
ICRU compact bone (No Corrections)	4.306	3.788	2.964	1.576
ICRU compact bone (Corrected) (Backscatter ratios at SSD=50 cm & f.S. 10x10 cm^2)	3.614	3.218	2.634	1.663

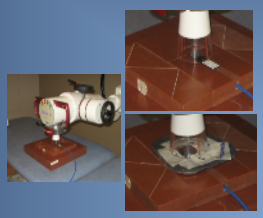
Clinical application

SSD vs potential errors



1 mm SSD error

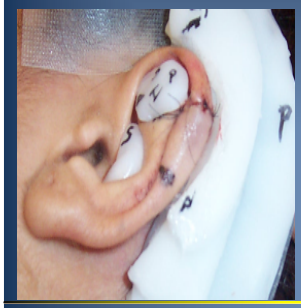
SSD (cm)	20	50
ISL	$(20.1/20)^2=1.010$	$(50.1/50)^2=1.004$
Error(%)	1.0%	0.4%

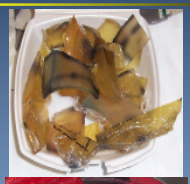


Custom Shielding

- Entrance shielding: lead sheet, Cerrobend cutout
- Exit shielding: lead, tungsten (eye shielding) (coated)

Cavity filling

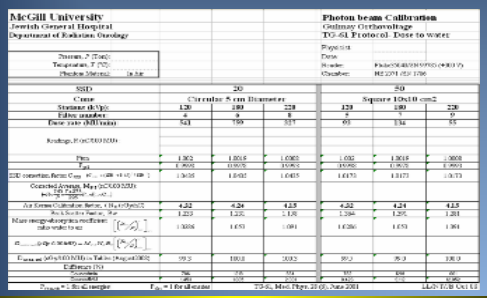




Quality assurance

Quality Assurance

Physics QA



McGill University
Jewish General Hospital
Department of Radiation Oncology

Photon beam Calibration
Ordinary Orthovoltage
TG-61 Protocol. Dose to water

Pressure, P (Torr):
Temperature, T (°C):
Physician Initials: In Air

Physicist:
Date:
Reader: Fricke/SM/JS/YS/YO (+RO?)
Chamber: NE 2571 /S/ 1786

SSD	20			50		
Cone	Circular 5 cm Diameter			Square 10x10 cm2		
Stainless (kVp)	120	180	220	120	180	220
Fulcy number	4	9	8	7	7	9
Dose rate (cGy/min)	541	589	557	61	134	55
Readings, R (nC/100 100)						
P_{ion}	1.002	1.0014	1.0003	1.002	1.0014	1.0008
T_{pol}	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
ESU conversion factor C_{ESU}	1.0035	1.0002	1.0015	1.0173	1.0173	1.0173
Corrected Average, M_{air} (nC/100 100)						
Air Kerma Calibration factor, N_K (cGy/nC)	4.32	4.24	4.15	4.32	4.24	4.15
Beam Quality factor, k_Q	1.253	1.235	1.18	1.284	1.295	1.281
Mass energy-absorption coefficient ratio water to air	1.0008	1.053	1.091	1.0286	1.053	1.091
Φ_{air} (gy/p.e.) [μ_{en}/ρ]$_{w,air}$						
$D_{water,air}$ (cGy/100 100) or Tables [μ_{en}/ρ]$_{w,air}$	99.3	100.8	100.5	99.2	99.9	100.9
Efficiency (%)						
Sensitivity	Nc	316	551	197	198	60
Sensitivity	1.00	1.00	2.00	0.00	0.00	0.00
D_{water} = 1 for air method	F_{ion} = 1 for air method			TG-61, Med. Phys. 28 (6), June 2001		LAA-TG61 Oct 03

Conclusions

- The AAPM TG-61 is a protocol for reference dosimetry of low energy photon beams (40 kV – 300 kV).
- The effective point of measurement for parallel-plate and cylindrical ionization chambers is the center of the sensitive air cavity.
- If the dose close to or at the surface is of interest, the in-air method should be used.
- If the dose at depth is of interest, the in-phantom method should be used.