Patient Dosimetry

(in diagnostic radiology)

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Why do we need dosimetry in DG :

✓Protection of patient

Balancing between necessary dose and quality of image

Optimization process

Why do we need dosimetry in DG :

✓Protection of patient

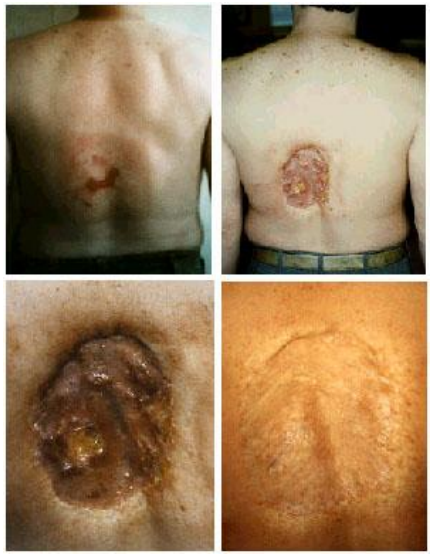
✓**Risk assessment**

20% accuracy for stochastic effects (partial irradiation, low doses, highly uncertain risk)

Deterministic effects : 7% accuracy

Paediatric examinations : 7% accuracy

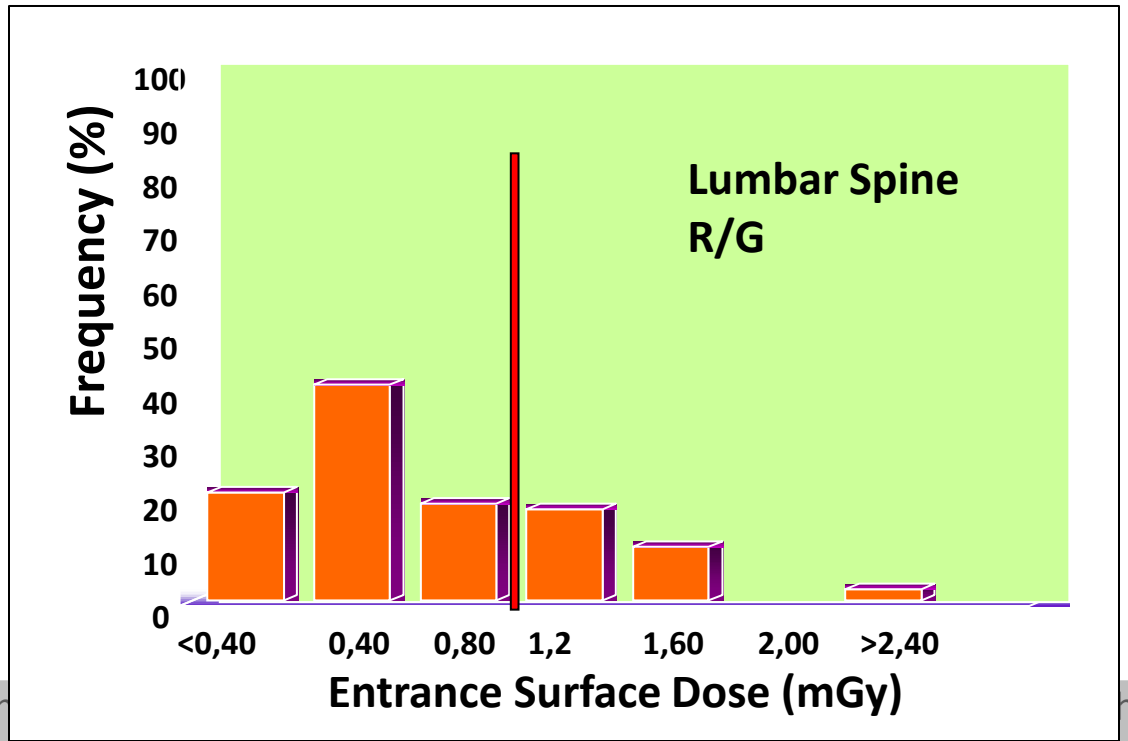
Doses to embryo/foetus : 7% accuracy



Why do we need dosimetry in DG :

- ✓Protection of patient
- ✓Risk assessment
- ✓**Comparisons - Diagnostic Reference Levels (DRL) – Collective dose (dose to population, dose per caput)**

Comparative dose measurements : 7% accuracy



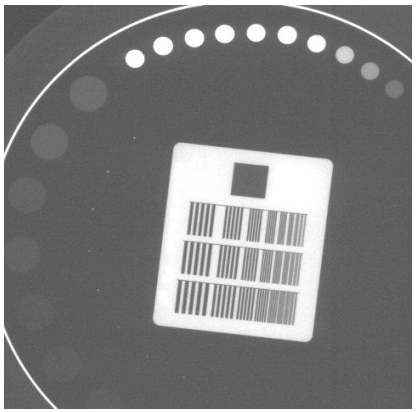
Why do we need dosimetry in DG :

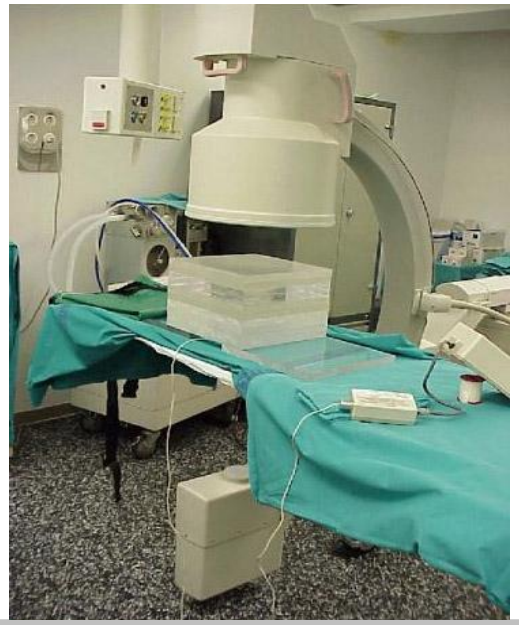
- ✓Protection of patient
- ✓Risk assessment
- ✓Diagnostic (Guidance) Reference Levels – DRL
- ✓**Quality Assurance and equipment testing**

provide confidence for optimum quality and minimum doses

- Baseline values
- QC & comparison with baselines

7% accuracy





Why do we need dosimetry in DG :

- ✓Protection of patient
- ✓Risk assessment
- ✓Diagnostic (Guidance) Reference Levels – DRL
- ✓Quality Assurance and equipment testing
- ✓**Radiation surveys**

exposure levels & potential risks

Accuracy 20% is sufficient

Reference material

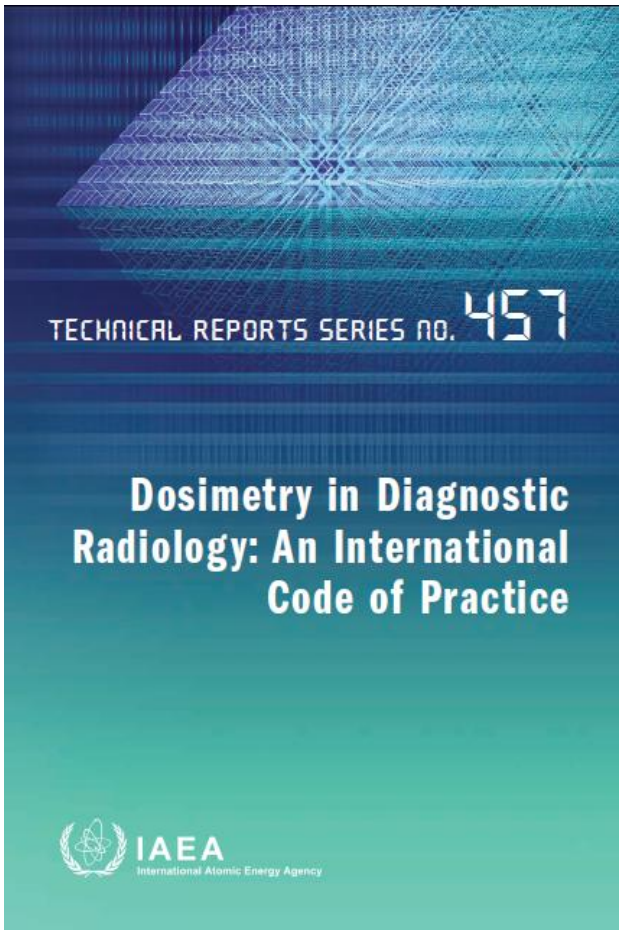
... many

Patient dosimetry for x rays used in medical imaging

- ICRU Report 74, published in 2005

Dosimetry in diagnostic radiology an international code of practice

- IAEA Technical Reports Series No 457, 2007



Contents

- ✓ Clinical dosimetry - Dose measurements
  - Instrumentation
  - Dosimetry protocols
    - Radiography
    - Fluoroscopy & Interventional
    - Mammography
    - CT
- ✓ Patient dosimetry
- ✓ Diagnostic Reference Levels (DRL)
  - Local - Regional – National
- ✓ Collective Dose - Effective dose

Clinical measurements

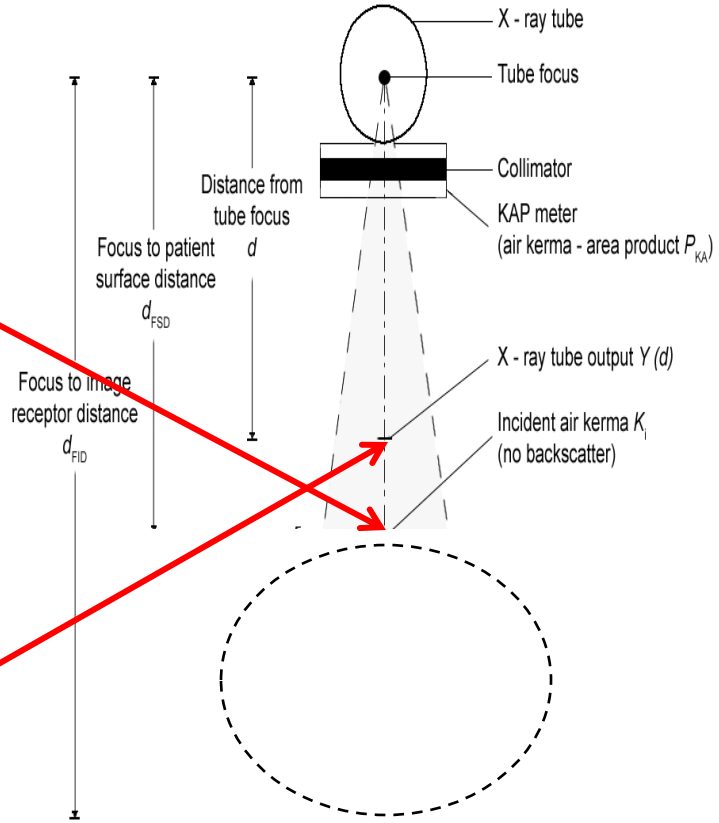
- **On patient directly,** using TLDs placed on skin or using KAP (DAP) meters
- **Using phantoms,** to simulate patient and define exposure conditions / settings (mAs, kV, etc)
- **In air,** using appropriate exposure settings (collected from patient examination)

Clinical measurements - Dosimetric quantities

✓ **Incident air kerma K_i (mGy)**

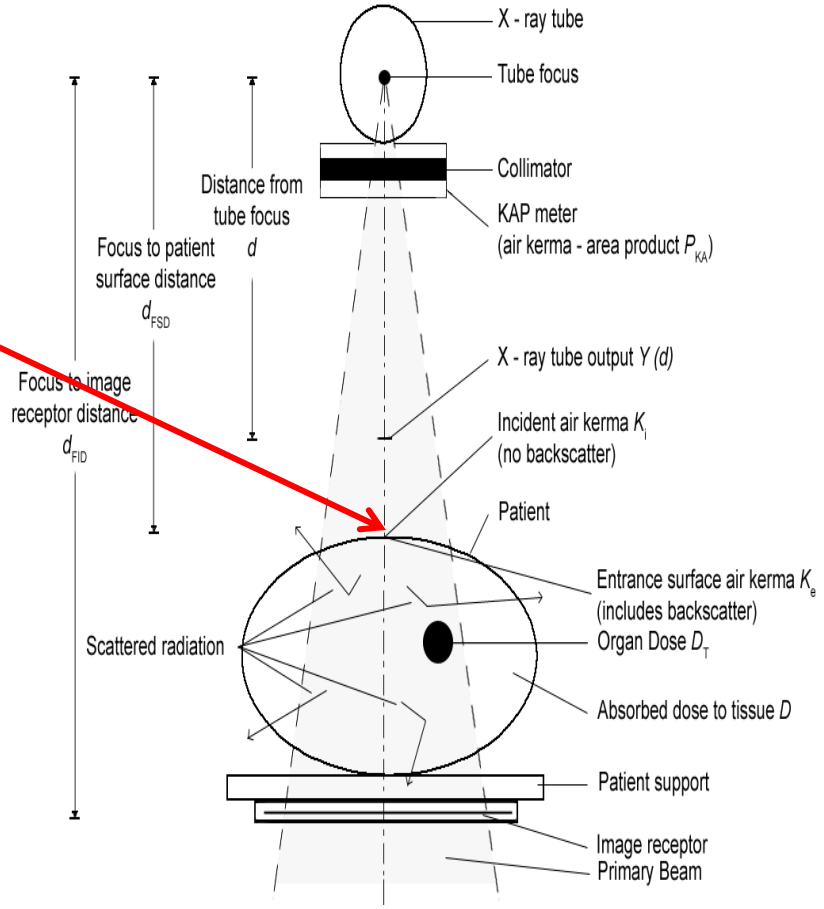
- measured in air at a point that corresponds to patient skin (without patient presence).
  - Using phantoms to “trigger” mAs or
  - using known or reference mAs.

- calculated from measured tube output **(mGy/mAs)**



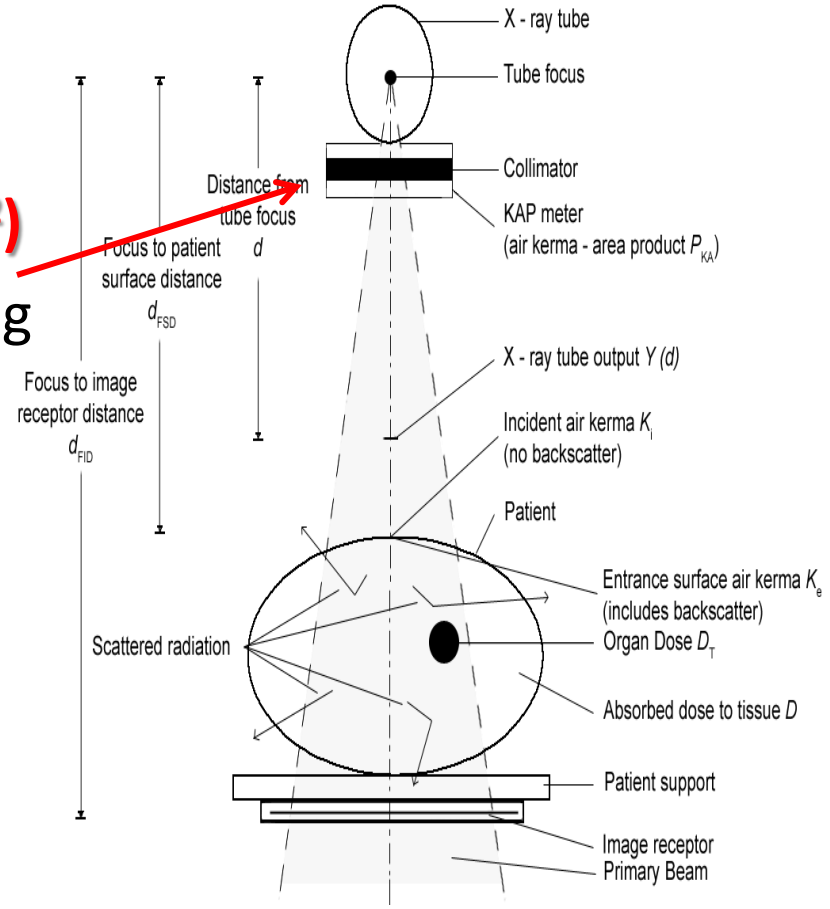
Clinical measurements - Dosimetric quantities

- ✓ Incident air kerma K_i
- ✓ **Entrance surface air kerma, K_e (mGy)**
- measured on patients using TLDs
- calculated from K_i and using appropriate backscatter factors, B



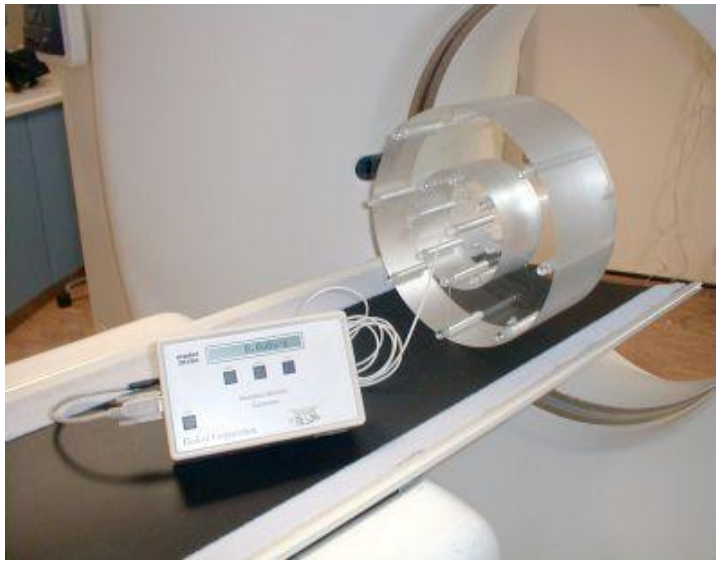
Clinical measurements - Dosimetric quantities

- ✓ Incident air kerma K_i
- ✓ Entrance surface air kerma K_e
- ✓ **Air kerma-area product P_{KA} (mGy cm^2)**
- measured during patient exam or using phantoms



Clinical measurements - Dosimetric quantities

- ✓ Incident air kerma K_i
- ✓ Entrance surface air kerma K_e
- ✓ Air kerma-area product P_{KA}
- ✓ **Air kerma-length product P_{KL} (mGy cm)**
  - CT dosimetry



- ✓Dose measurements (clinical measurements)
  - **Instrumentation**
  - Dosimetry protocols - Procedures
- ✓Patient dosimetry
- ✓Diagnostic Reference Levels (DRL)
  - Local - Regional – National
- ✓Collective Dose - Effective dose

Instrumentation -Dosimeters

Depending on the application there are various instrument categories and modes of operation

- Conventional diagnostic radiology (50-150 kV)
- Mammography
- CT (air kerma length product)
- KAP meters air kerma area product (Angiography, fluoroscopy)

- ➢ Radiographic mode (accumulated – integrating - “dose”)
- ➢ Fluoroscopic mode (“dose” rate)
- ➢ Cine mode (pulsed “dose”)

Instrumentation -Dosimeters

Many types of dosimeters are commercially available

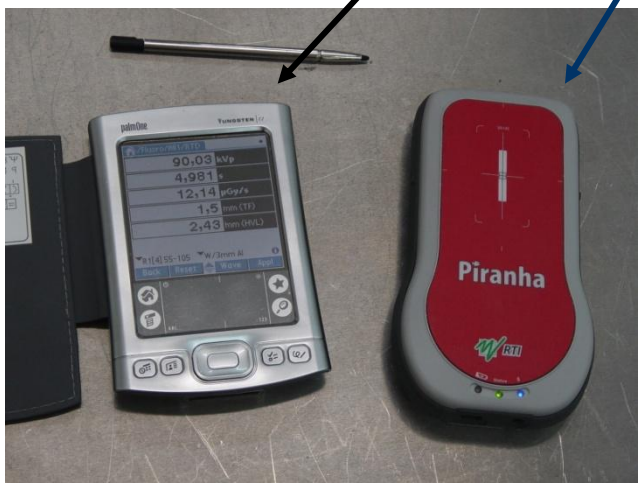
Dosimeter

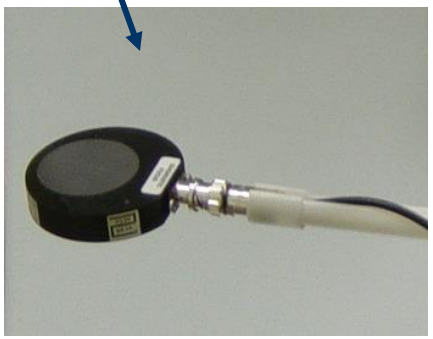
Measuring assembly (electrometer, main unit)

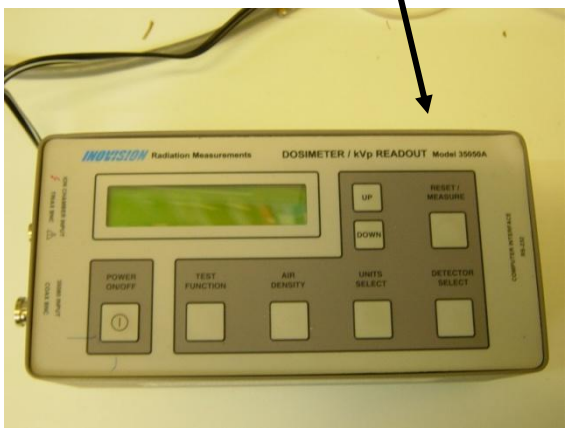
Detector

Ionization chamber

Solid state detector

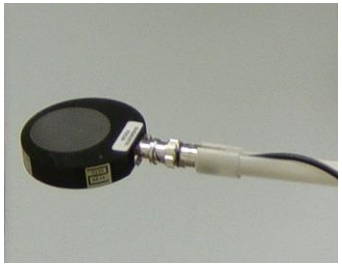


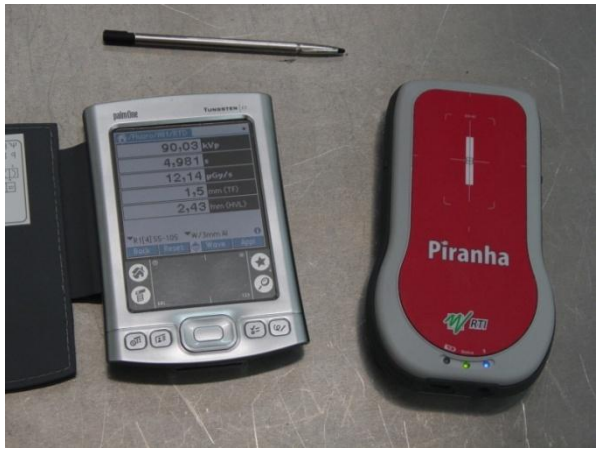




Instrumentation -Dosimeters

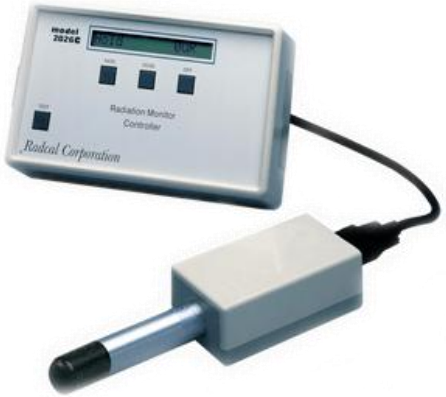
Dosimeters for Clinical Dosimetry



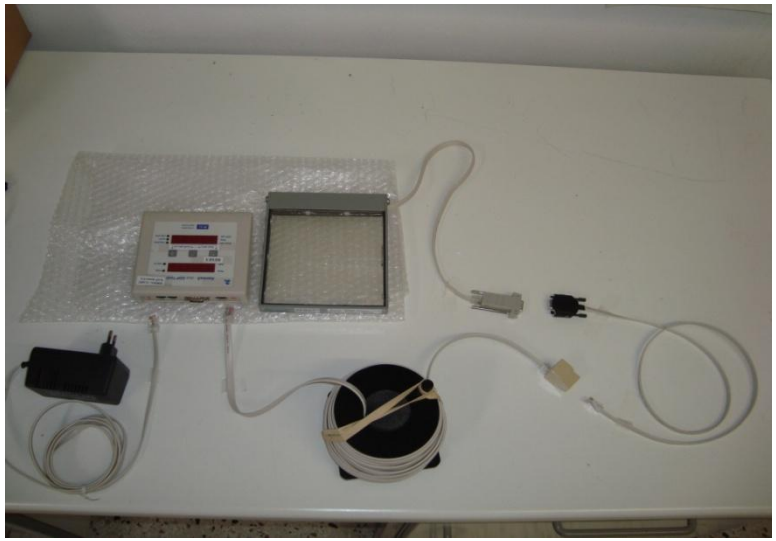


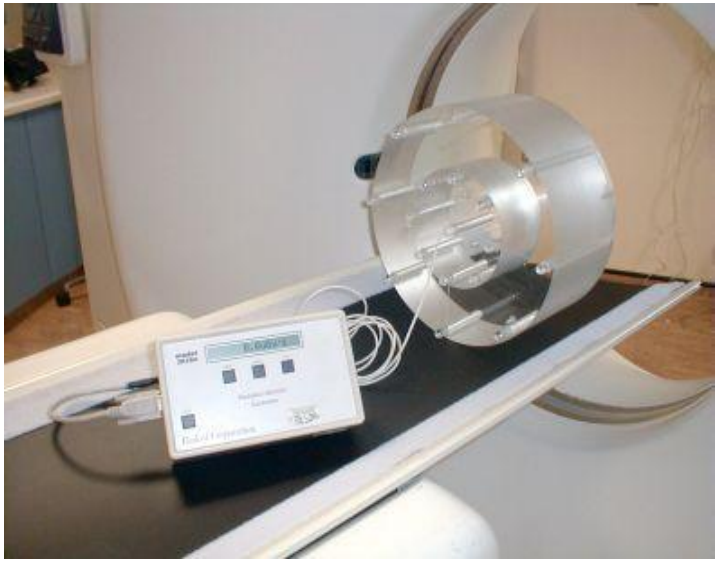
Ionization chamber

Solid state



Dosimeters for Clinical Dosimetry





Air kerma determination :

$$K = M_Q \, N_{K,Q_O} \prod_i k_i$$

Usually (but not necessarily correctly) :

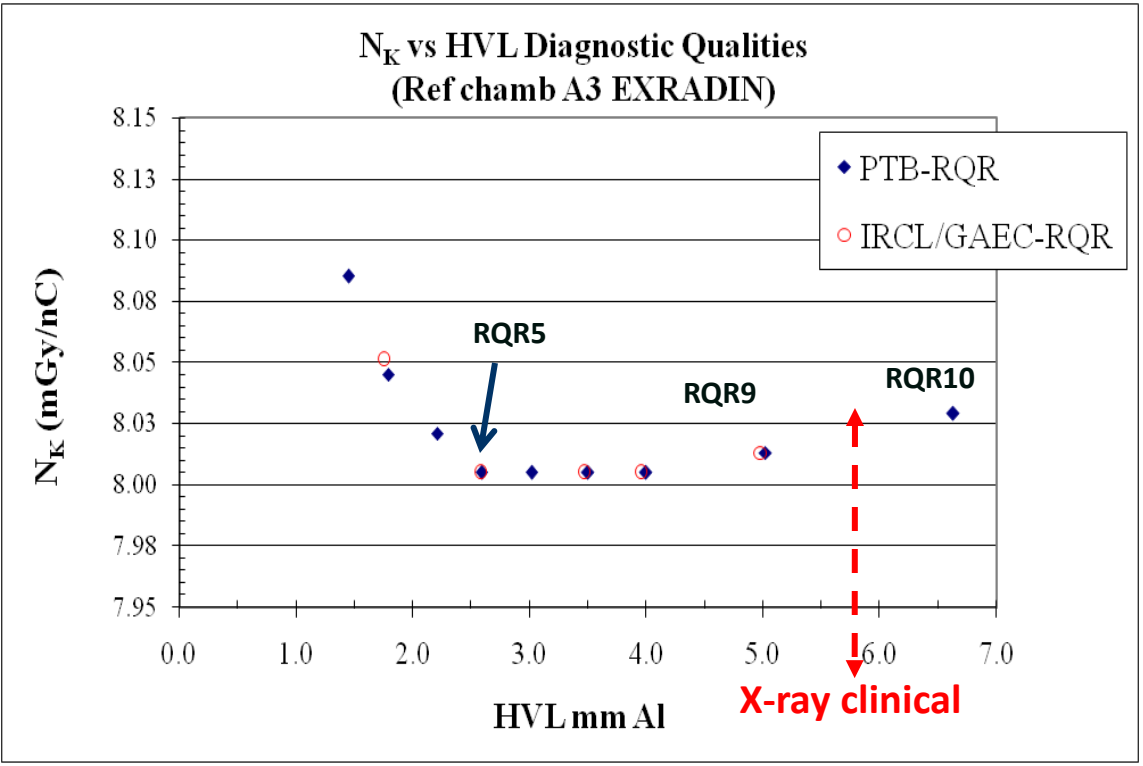
$$\prod_i k_i = k_{P,T} \cdot k_Q \cdot \overbrace{k_S k_{dist} k_{lin} k_{dir} k_{emc} k_{fh} k_{lt} k_{ms}}^{1} = k_{P.T} \cdot k_Q$$

Tips (Sources of uncertainties) :

- Energy corrections for the beam quality (i.e. HVL - not to the applied kVp)
- Air density corrections should be considered. Typical $k_{P,T}$ = 1.03 (θ=22°C and P=99 kPa), resulting in a 3 % deviation, if not applied. **For solid state $k_{P,T}$ = 1**
- Careful use of dosimeters that apply automatic corrections for temperature and/or pressure, especially for :
  - position of device (having the sensors) inside room
  - accuracy of sensors
  - temperature reference value (to 20°C or 22 °C)

Energy dependence of response

Standard beam qualities during calibration : RQR series – RQR5 (70 kV reference)

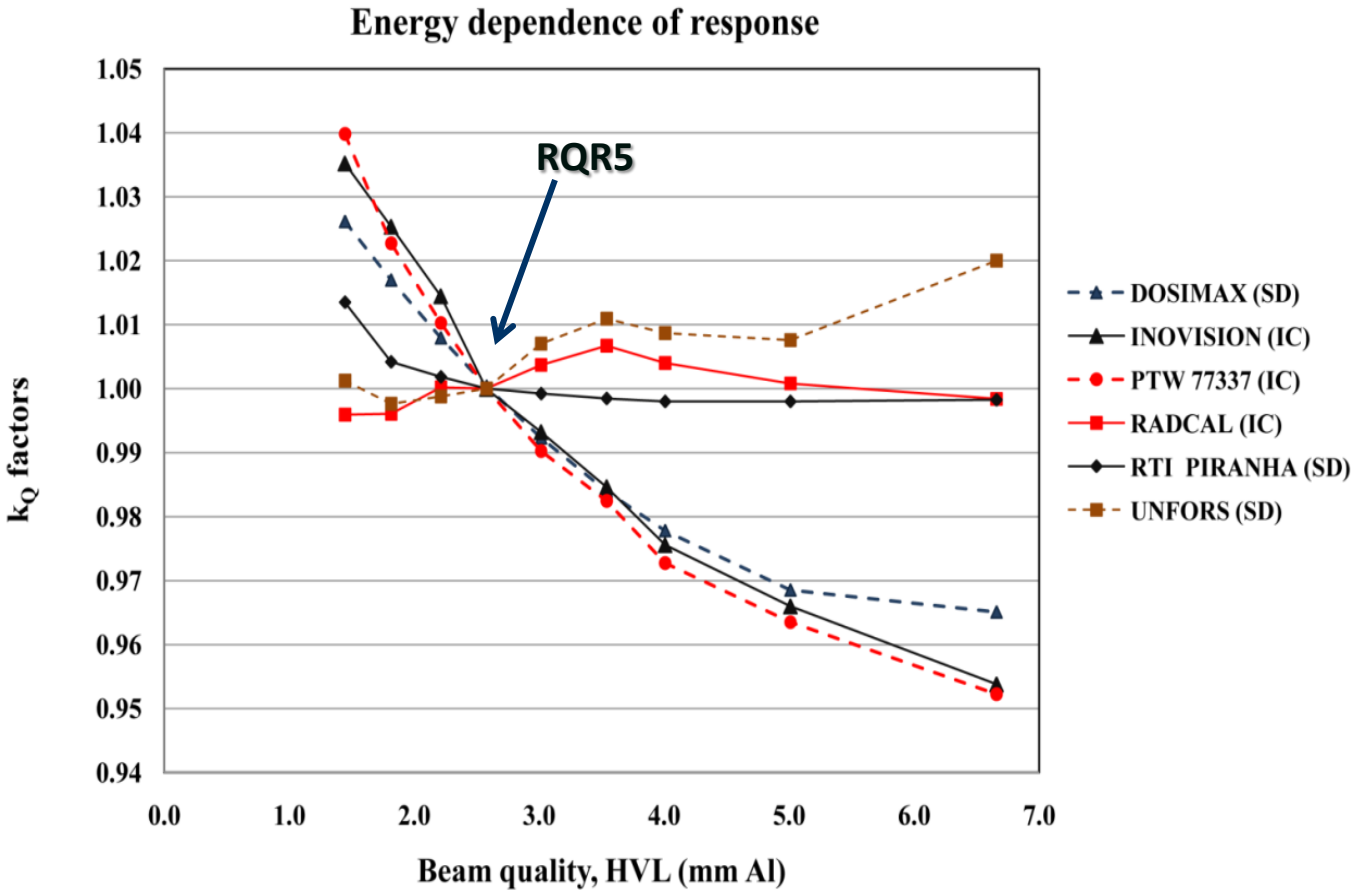


Example :
Clinical X-ray tube with
HVL = 5.8 mm Al

Calibration coefficient, N_K = ?

i. either at 5 mmAl (RQR9)
ii. or interpolation

Energy dependence of response



Instrumentation -Dosimeters

Solid state

Advantages

- produce large signals from modest amounts of radiation
- rigid and robust
- do not require pressure correction
- convenience to use

Modern models Compensation

- use of multi element ST
- use of movable filters
- compensation and processing of signals

CAUTIONS

- energy dependant
- may be inappropriate for HVL measurements, due to energy depend.
- directional, positioning & angular dependency
- ageing effects (regular calibration)
- lead (Pb) plate at the rear surface (not measuring backscatter)

Instrumentation -Dosimeters

IEC 61767 : 1997 dosimeter performance characteristics			
Influence quantity	**Minimum rated ranges**	**Reference conditions**	**Limits of variation**
Intrinsic error, air kerma Intrinsic error, air kerma rate	> 100 μGy > 100 μGy/s	reference	± 5% ± 5%
Radiation quality of unattenuated beam (GR)	50 – 150 kV W anode, 2,5mmAl filtration	RQR5	± 5%
Radiation quality (Mammo GR)	22 – 40 kV Mo anode, Mo filtration	RQR-M2	± 5%
Air kerma rate	as stated by the manufacturer	as at calibration	± 2% [a]
Incident radiation angle	± 5°	reference angle	± 3%
Field size	minimum : manufacturer specification max : 35 cm x 35 cm	as at calibration	± 3%
Air pressure	80 kPa – 106,0 kPa	101.3 kPa	± 2%
Temperature	15 – 35 °C	20 °C	± 3%
Operating voltage	-15% to +10%	Nominal	± 2%
Electromagnetic compatibility	IEC 61000-4	Without EM	± 5%

Instrumentation -Dosimeters

RECOMMENDED SPECIFICATIONS OF DETECTORS OF A REFERENCE CLASS DOSIMETER, BY APPLICATION [IAEA TRS 457]

Application	Type of detector	kV	I.E. %	Resp Var %	Range of air kerma rate	
					Unattenuated beam	Attenuated beam
General radiography	Cylindrical, spherical or plane-parallel	60 - 150	3.2	±2.6	1 mGy/s – 500 mGy/s	10 μGy/s – 5 mGy/s
Fluoroscopy	Cylindrical, spherical or plane-parallel (preferable)	50 – 100	3.2	±2.6	10 μGy/s – 10 mGy/s	0.1 μGy/s – 100 μGy/s
Mammography	Plane-parallel	22 – 40	3.2	±2.6	10 μGy/s – 10 mGy/s	
Computed tomography[1)]	Cylindrical (pencil type)	100 – 150	3.2	±2.6	0.1 mGy/s – 50 mGy/s	
Dental radiography	Cylindrical or -plane-parallel	50 – 90	3.2	±2.6	1 μGy/s – 10 mGy/s	

Instrumentation – “Passive” solid state dosemetres (TLD, OSL)

TLDs

TLDs are available in various forms (e.g. powder, chips, rods, ribbons, etc.) and made of various materials.
Most commonly used in medical applications are based on lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti)
but other materials like LiF:Mg,Cu,P, Li2B4O7:Mn, CaSO4:Dy and CaF2:Mn

Instrumentation – "Passive" solid state dosemetres (TLD, OSL)

application, energy dependence or response, etc

TL material	Form	Glow peak °C	Emmission maximum nm	Z_{eff}	Relative sensitivity	Linear range Gy	Fading	Annealing
LiF:Mg,Ti	Powder, chips, rods, discs	210	425	8.14	1	$5x10^{-5}$ to 1	<5% per year	400°C, 1 h + 80°C, 24 h
LiF:Mg,Ti,Na	Powder, discs	220	400	8.14	0.5		NA	500°C, 0.5 h
LiF:Mg,Cu,P	Powder, discs	232	310(410)	8.14	15-30	10^{-6} to 10	<5% per year	240°C, 10 min
$Li_2B_4O_7$:Mn	Powder	210	600	7.4	0.15-0.4	10^{-4} to 3	5% in 2 months	300°C, 15 min
Al_2O_3:C	Powder, discs	250	425	10.2	30	10^{-4} to 1	3% per year	300°C, 30 min
$CaSO_4$:Dy	Powder, discs	220	480(570)	15.3	30-40	10^{-6} to 30	7-30% in 6 months	400°C, 1 h
CaF_2:Dy	Powder	200(240)	480(575)	16.3	16	10^{-5} to 10	25% in 4 weeks	600°C, 2 h
BeO	Discs	180 to 220	330	7.13	0.7-3	10^{-4} to 0.5	7% in 2 months	600°C, 15 min

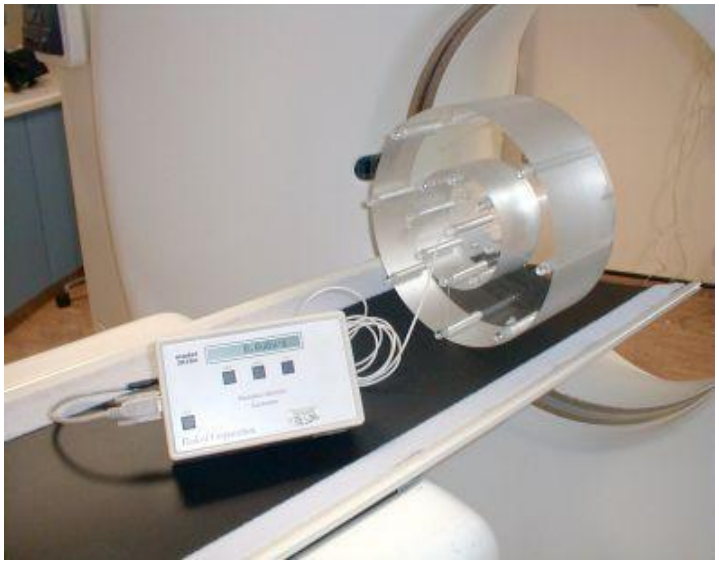
!!!

- annealing process
- fading
- energy response
- accuracy - calibration

Instrumentation - Phantoms

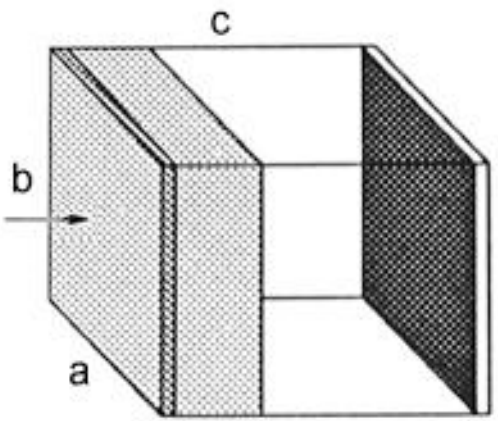
Phantoms are used

- when Automatic Exposure Control (AEC) is used (to “trigger” mAs)
- to simulate scattered radiation conditions
- in CT dosimetry

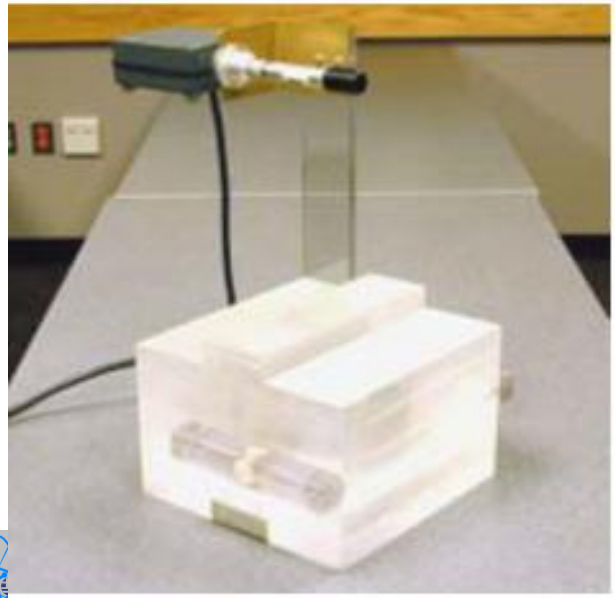


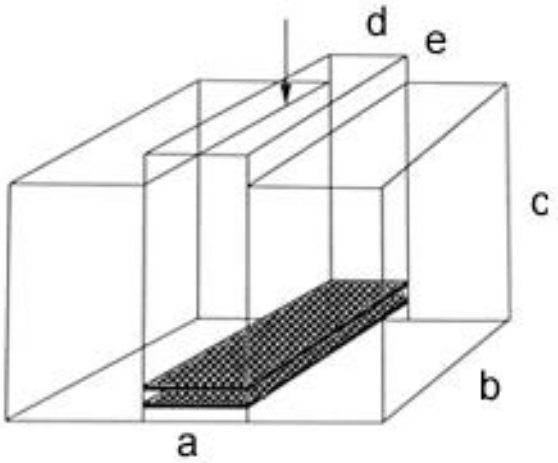
Instrumentation - Phantoms

- PMMA phantoms (eg typical 185 mm thick for std patient)
- ICRU phantoms
  - PMMA walls filled with water (eg 200 mm for std patient)
- ANSI phantoms
  - PMMA + Al



a = 254 mm
b = 254 mm
c = 267 mm





a = 254 mm
b = 254 mm
c = 169 mm

d = 70 mm
e = 24 mm

- ✓Dose measurements (clinical measurements)
  - Instrumentation
  - **Procedures – Dosimetry protocols**
- ✓Patient dosimetry
- ✓Diagnostic Reference Levels (DRL)
  - Local - Regional – National
- ✓Collective Dose - Effective dose

Dosimetry methodology : Radiography

Phantom makes sense if AEC is used

For manual settings :
kV, mA, mAs

usually

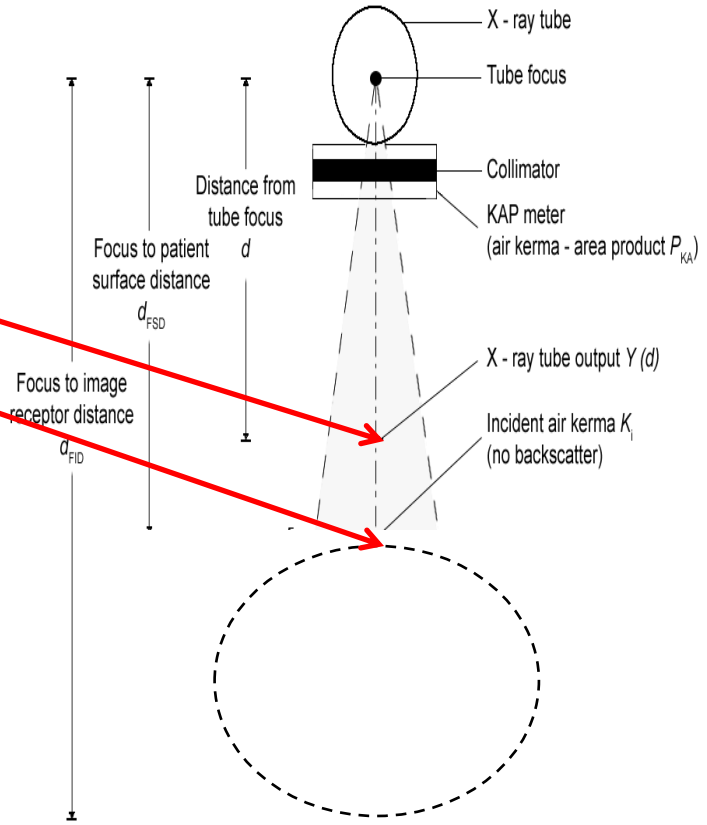
exposure settings for standard patient (eg 75 kg, 170 cm height)

or according to clinical data collected (kV, mAs, FFD, FSD)

Dosimetry methodology : Radiography

Calculation of Incident air kerma, K_i

$$K_i = K(d)\left(\frac{d_{\mathrm{FTD}} - d_{\mathrm{m}}}{d_{\mathrm{FTD}} - t_{\mathrm{P}}}\right)^2$$



Distance correction from chamber to patient surface:

d_{FTD} : measured tube focus-to-patient support distance

d_m : distance from the table top (or a wall Bucky) to the reference point of the chamber at the measurement position

t_P : thickness of a standard chest or abdomen/lumbar spine of astd patient (225 mm chest / 230 Abdomen and LS)

Dosimetry methodology : Radiography

Calculation of patient entrance surface air kerma, Ke

Appropriate backscatter factor (B) for clinical beam HVL & field-size,

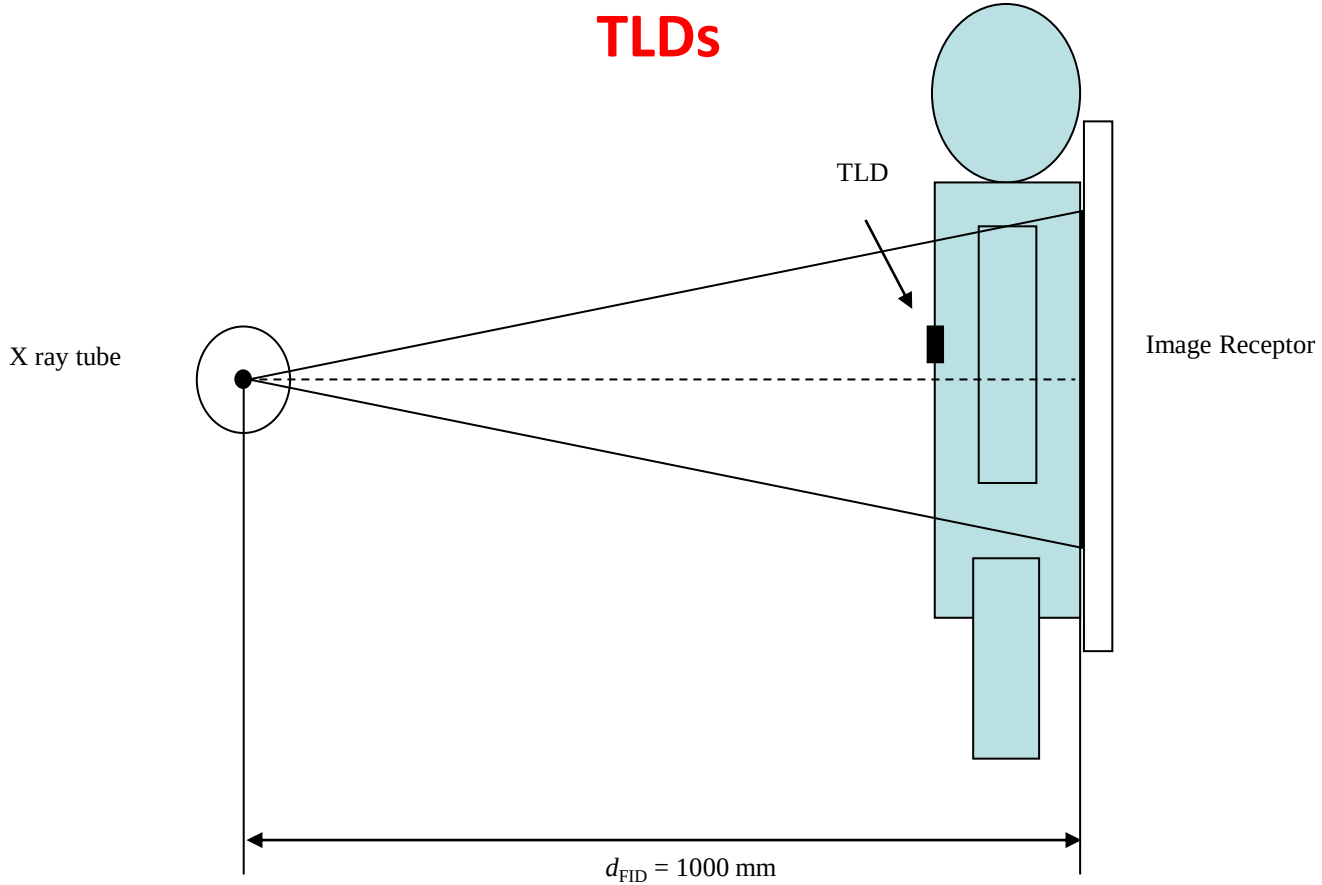
$$K_e = K_i B$$

TABLE VIII.1. BACKSCATTER FACTORS, *B*, FOR WATER, ICRU TISSUE AND PMMA FOR 21 DIAGNOSTIC X RAY BEAM QUALITIES AND FOR THREE FIELD SIZES AT A FOCUS TO SKIN DISTANCE OF 1000 mm*

Tube voltage (kV)	Filter	Backscatter factor (*B*)									
		Field size	100 mm × 100 mm			200 mm × 200 mm			250 mm × 250 mm		
		HVL (mm Al)	Water	ICRU tissue	PMMA	Water	ICRU tissue	PMMA	Water	ICRU tissue	PMMA
50	2.5 mm Al	1.74	1.24	1.25	1.33	1.26	1.27	1.36	1.26	1.28	1.36
60	2.5 mm Al	2.08	1.28	1.28	1.36	1.31	1.32	1.41	1.31	1.32	1.42
70	2.5 mm Al	2.41	1.30	1.31	1.39	1.34	1.36	1.45	1.35	1.36	1.46
70	3.0 mm Al	2.64	1.32	1.32	1.40	1.36	1.37	1.47	1.36	1.38	1.48
70	3.0 mm Al +0.1 mm Cu	3.96	1.38	1.39	1.48	1.45	1.47	1.58	1.46	1.47	1.59
80	2.5 mm Al	2.78	1.32	1.33	1.41	1.37	1.39	1.48	1.38	1.39	1.50
80	3.0 mm Al	3.04	1.34	1.34	1.42	1.39	1.40	1.51	1.40	1.41	1.52
80	3.0 mm Al +0.1 mm Cu	4.55	1.40	1.40	1.49	1.48	1.50	1.61	1.49	1.51	1.63
90	2.5 mm Al	3.17	1.34	1.34	1.43	1.40	1.41	1.51	1.41	1.42	1.53
90	3.0 mm Al	3.45	1.35	1.36	1.44	1.42	1.43	1.53	1.42	1.44	1.55
90	3.0 mm Al +0.1 mm Cu	5.12	1.41	1.41	1.50	1.50	1.51	1.62	1.51	1.53	1.65
100	2.5 mm Al	3.24	1.34	1.34	1.42	1.40	1.41	1.51	1.41	1.42	1.53
100	3.0 mm Al	3.88	1.36	1.37	1.45	1.44	1.45	1.55	1.45	1.46	1.57

Dosimetry methodology : Radiography

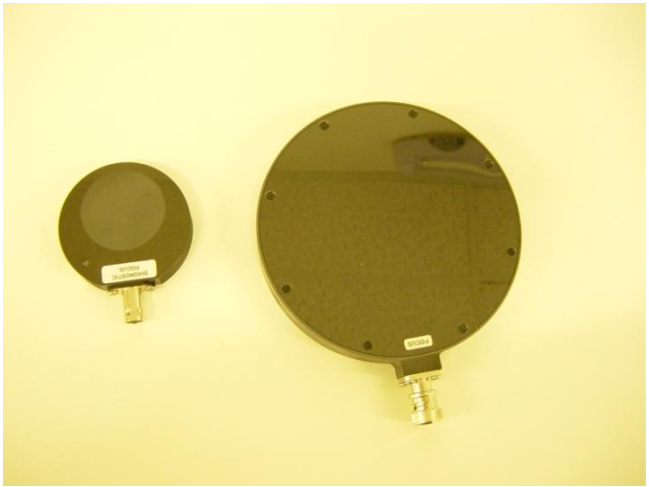
Determination of patient doses from measurements on patients with TLDs



$$K_e = \overline{M} N_{K,Q_0} k_Q k_f$$

Dosimetry methodology : Fluoroscopy & Interventional radiology

Fluoroscopy	Phantom	Entrance surface air kerma rate	Measured directly on a phantom or calculated from the incident air kerma rate using backscatter factors.
	Patient	Air kerma–area product	Maximum skin dose is also measured.



Dosimetry methodology : Fluoroscopy & Interventional radiology

- 4 geometries
  - Under couch
  - Over couch
  - C-arm
  - C-arm-lat

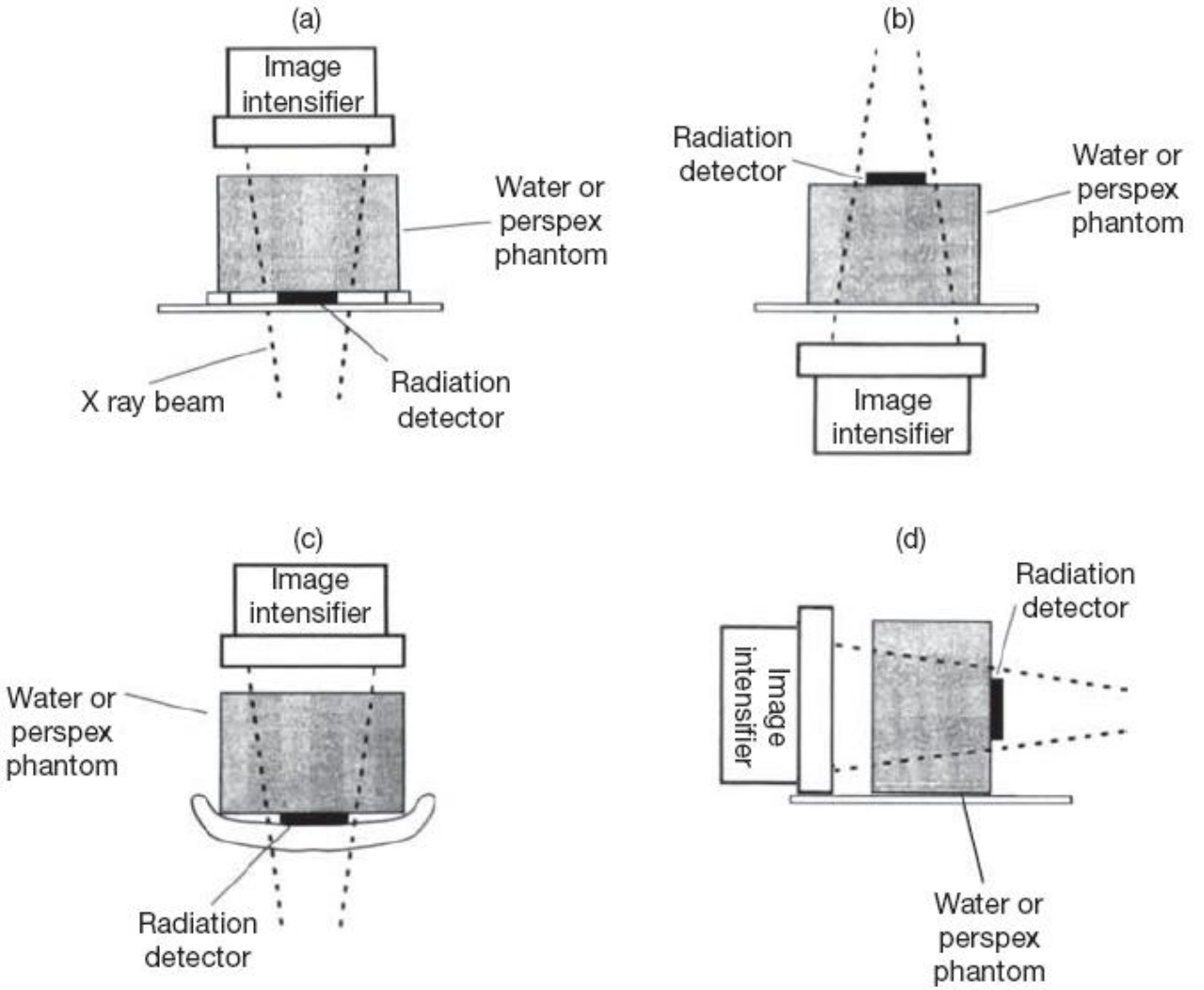


FIG. 8.4. Configuration for measurement of patient entrance surface air kerma: (a) an under couch installation, (b) an over couch installation, (c) a C-arm unit, (d) C-arm unit, lateral exposures or when a couch used clinically is not available (after Martin et al.

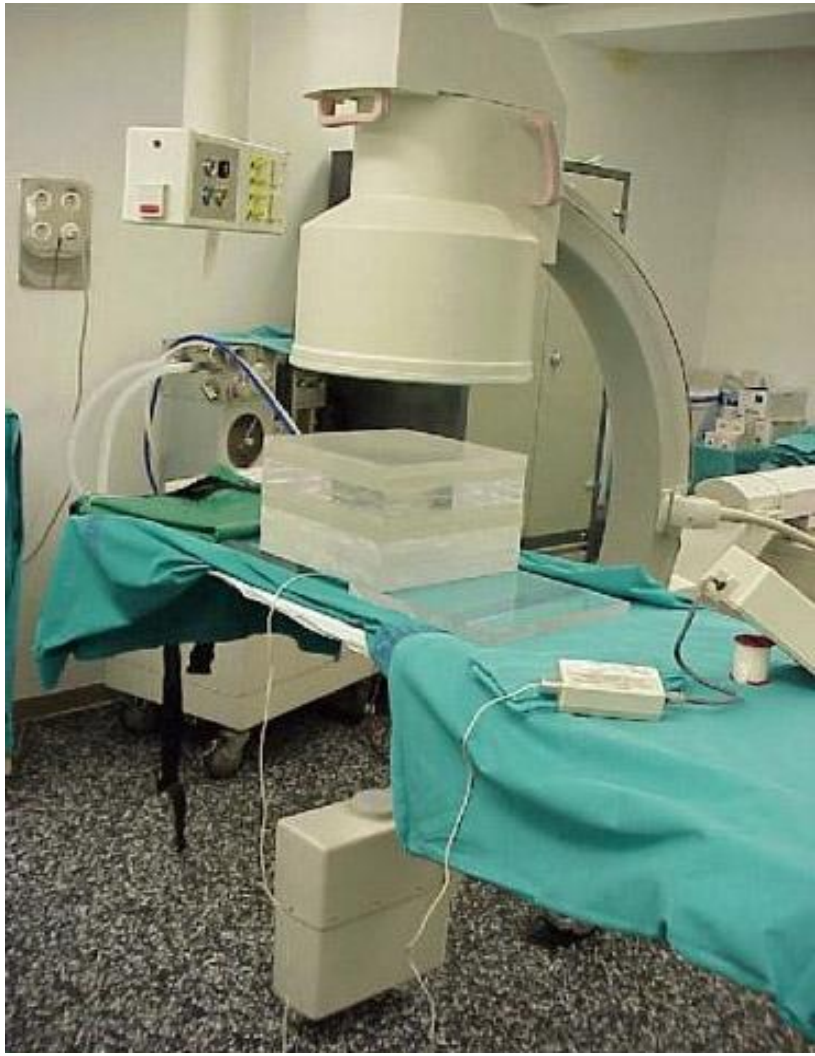
Dosimetry methodology : Fluoroscopy & Interventional radiology

Entrance surface air kerma rate

$$\dot{K}_e = \bar{\dot{M}}\, N_{K,Q_0} k_Q k_{TP}$$

CAUTION
when using solid state detector!!
they usually have lead (Pb) back side plate.

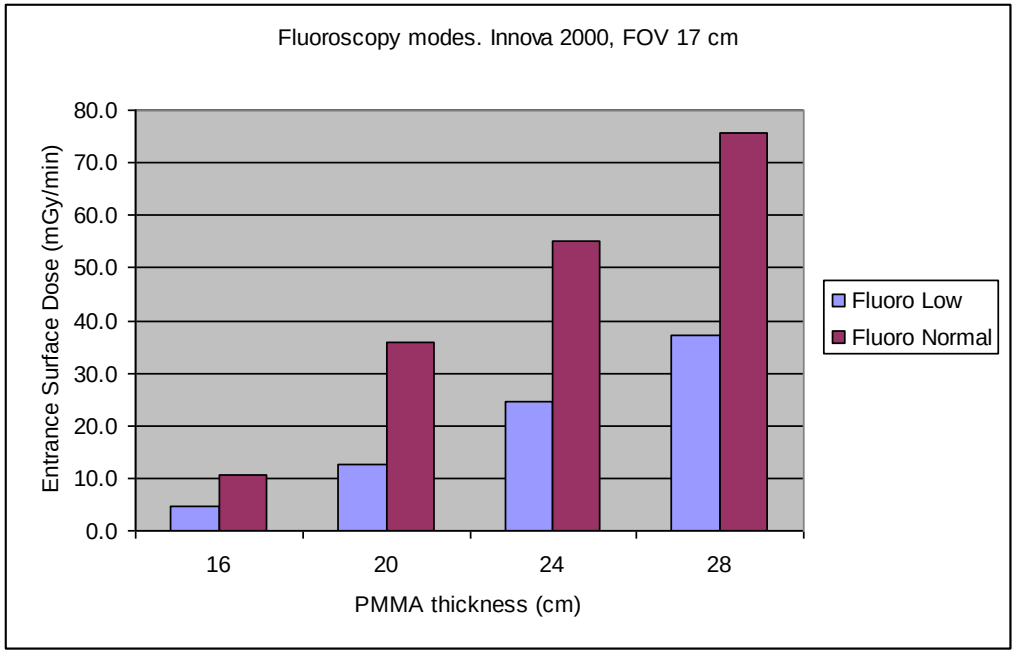
They measure
NEITHER entrance air kerma, since
backscatter is not measured (efficiently)
NOR incident air kerma, Ki,



Dosimetry methodology : Fluoroscopy & Interventional radiology

Ionisation chamber to measure phantom entrance surface air kerma rate (K_e)

Entrance surface air kerma for different fluoro modes and patient thickness



Data from
Renato Padovani, Udine, Italy

Fluoroscopy Dosimetry on Patients : KAP meters

- KAP meter with flat trasparent ionisation chamber

KAP may be :

- mounted on tube housing
- Portable and placed on tube exit (diaphgrams)
- is calculated from kV, filtration, mAs, diaphragms positions

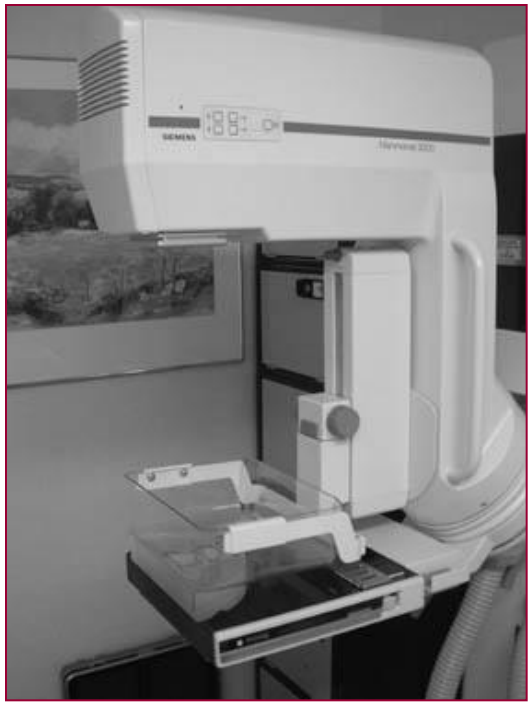
Air kerma-area product, P_{KA} (= K · A) is independent of distance, so

KAP metew indiaction = P_{KA} on patient

Dosimetry methodology : Mammography

K_i Incident air kerma

K_e Entrance surface air kerma



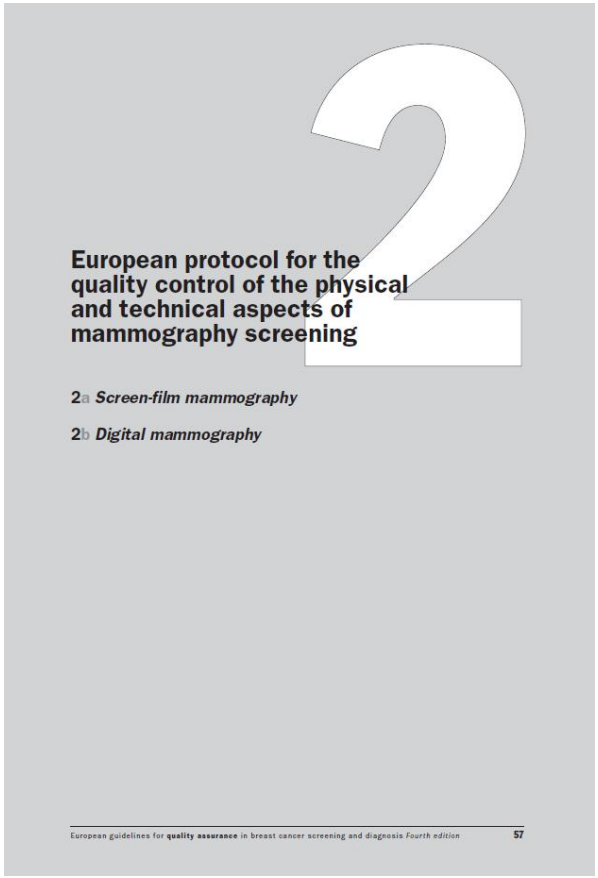
Dosimetry methodology : Mammography

Two different approches:

- **Measuremets using dosimeters and phantoms (45 mm PMMA, EU)**
- **Measurements using TLDs**

Dosimetry methodology : Mammography

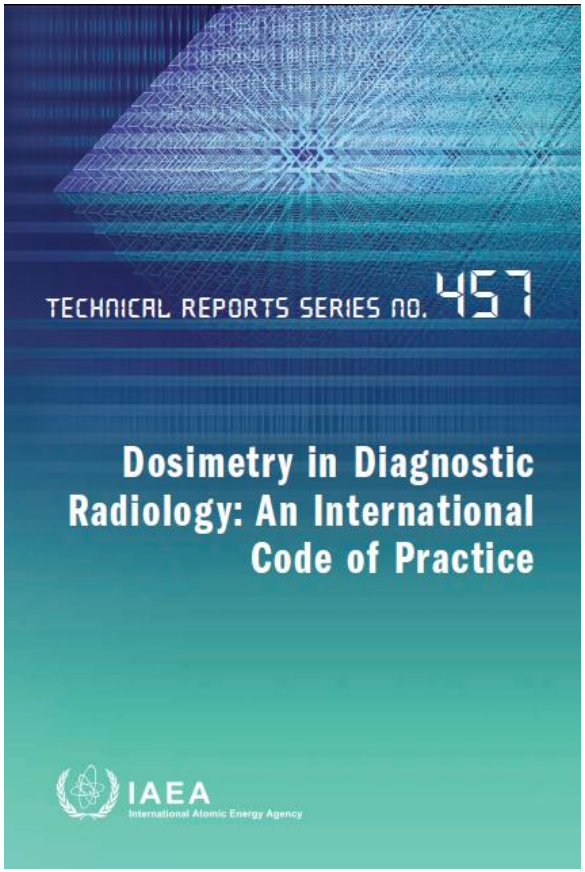
European protocol



ACR protocol

ACR®
AMERICAN COLLEGE OF RADIOLOGY
QUALITY IS OUR IMAGE

IAEA protocol



Dosimetry methodology : Mammography

Measurements using phantoms & Dosimeter

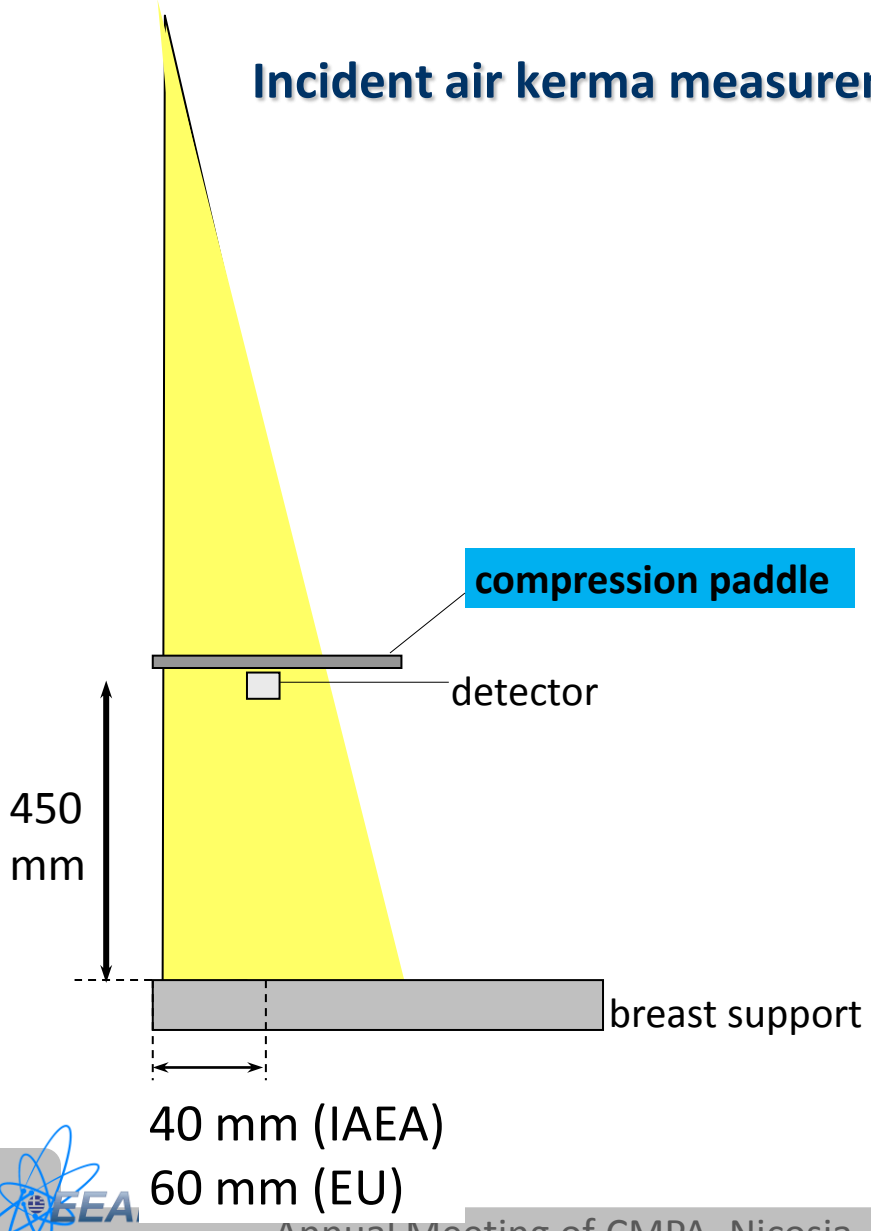
1. Knowledge of the parameters for correct exposure of the phantom ; determination of mAs

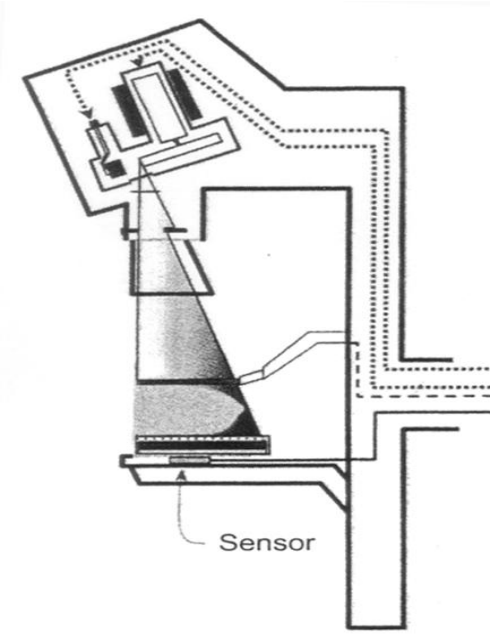
2. Measurement of incident air kerma;

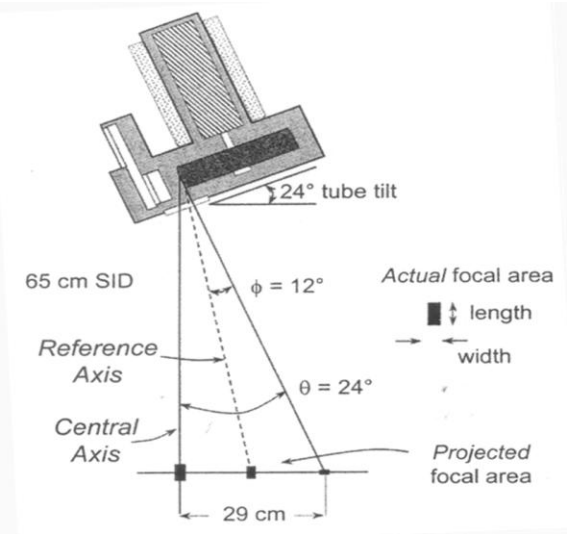
3. Measurements of HVL;

Dosimetry methodology : Mammography

Incident air kerma measurement

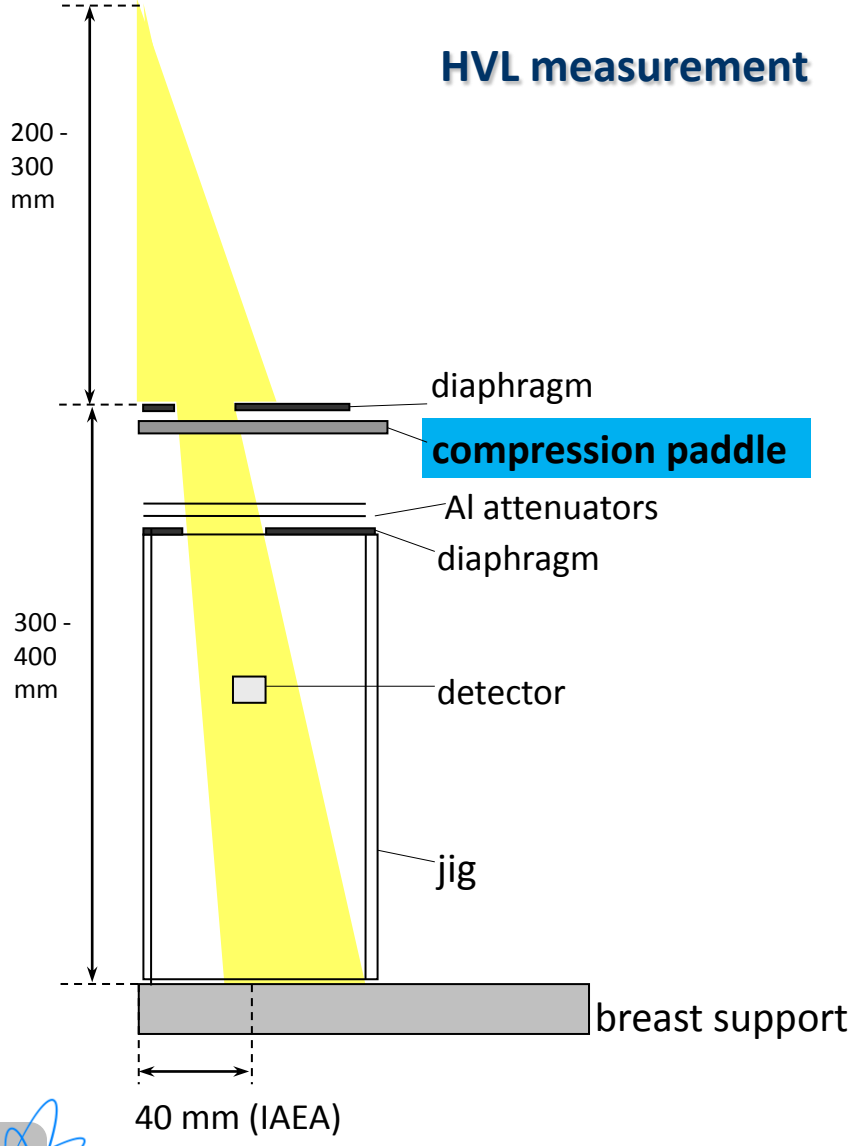


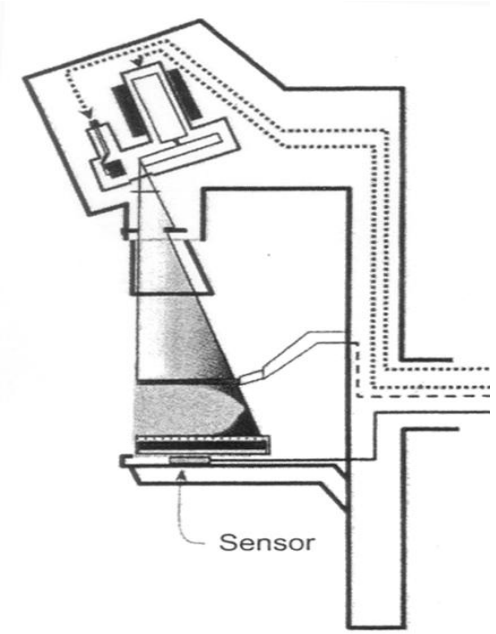


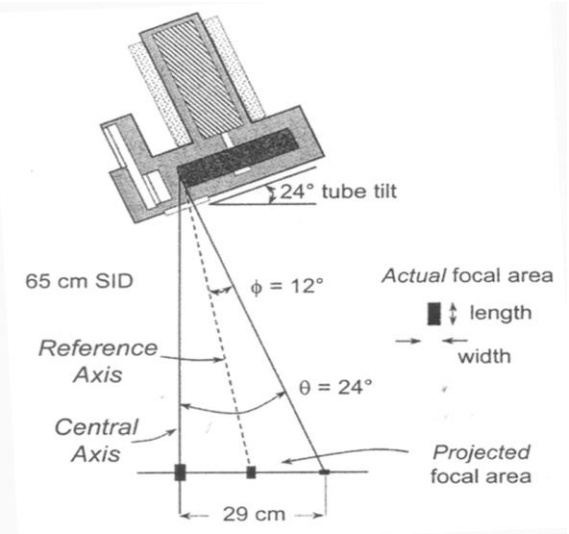


Dosimetry methodology : Mammography

HVL measurement







Dosimetry methodology : Mammography

Measurements using TLDs

- Phantom on the breast table
- TLDs on the surface of the phantom (NOT on patient breast) with the centre of the sachet 40 mm from the chest wall edge and centred with respect to the lateral direction
- Compression plate down onto the phantom (taking care not to damage TLDs).
- TLD measure the K_e

$$K_i = K_e / B = (M \cdot N_{KQo} \cdot k_Q \cdot k_f)/B$$

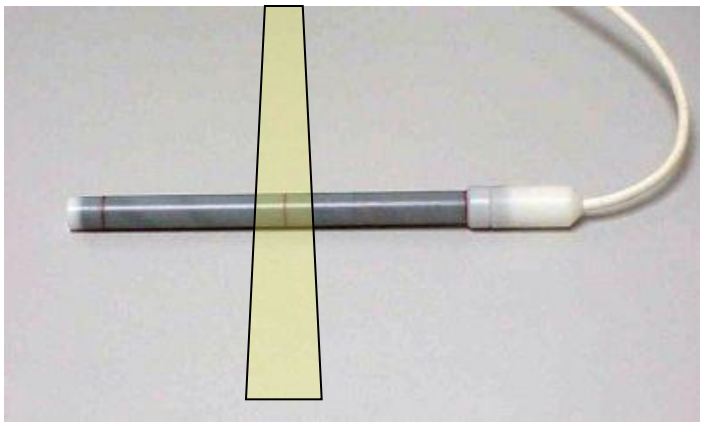
HVL (mm Al)	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
B	1.07	1.07	1.08	1.09	1.10	1.11	1.12	1.12	1.13

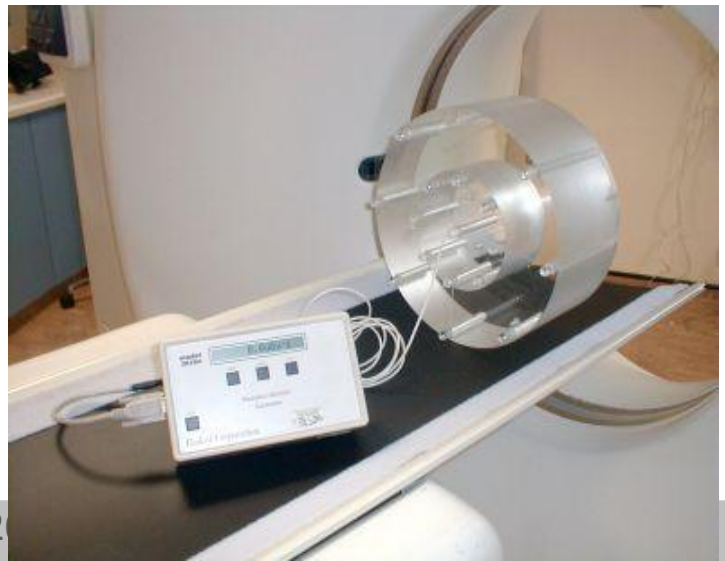
* Data taken from Ref. [8.2].

Dosimetry methodology : CT

CTDI, Computed Tomography Dose Index :

- measured with single axial scan only
- Measured on axis of scanner using pencil ionisation chamber
- Calculated as integral of air kerma along chamber divided by nominal beam width

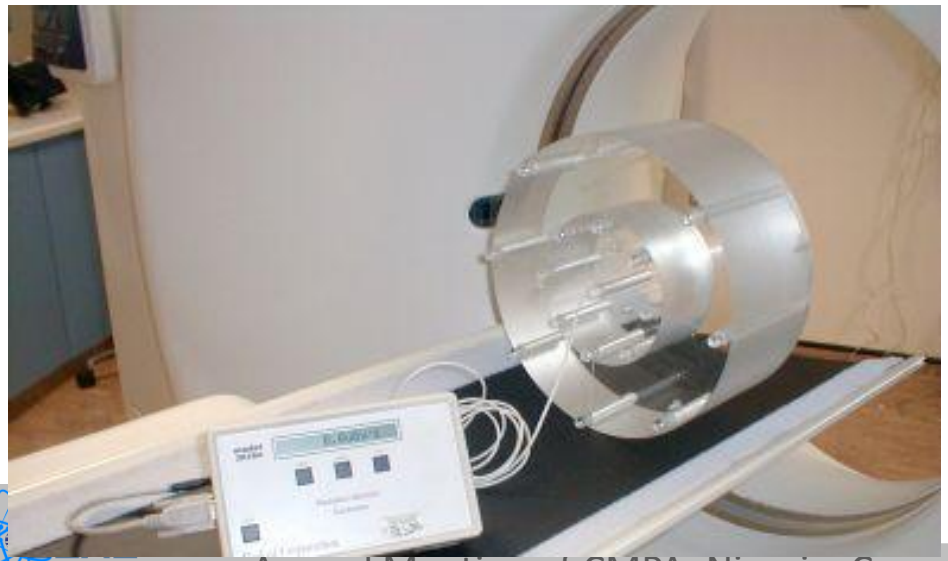


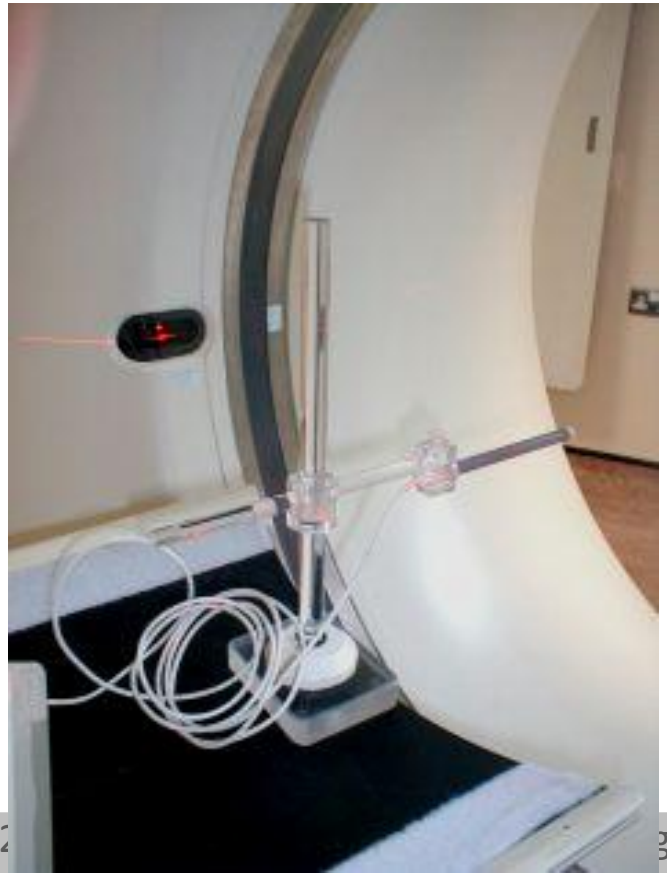


Dosimetry methodology : CT

- ✓ Cylindrical PMMA phantoms with holes for pencil chamber
  - 32 cm body phantom
  - 16 cm head phantom

- ✓ Measurements in air





Dosimetry methodology : CT

$C_{a,100}$ – CTDI measured in air, integrated over 100 mm, mGy

$$C_{\mathrm{a},100} = \frac{P_{KL}}{NT} = \frac{1}{NT}\,\overline{M}\,N_{P_{\mathrm{KL}},Q_0}\,k_Q\,k_{\mathrm{TP}}$$

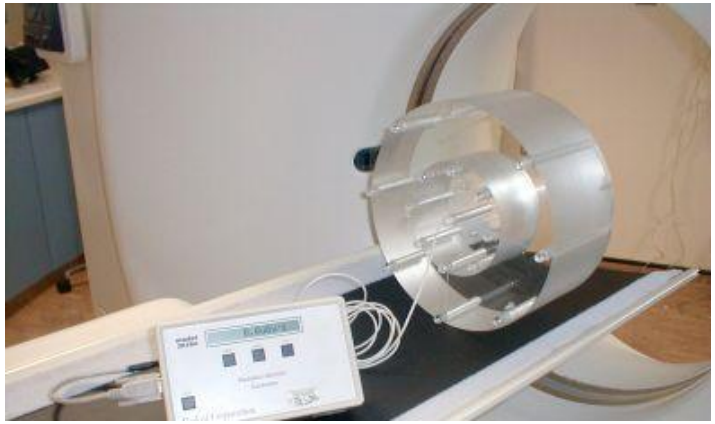
$\overline{M}$: mean value of dosimeter readings
k_{TP} : correction factor for temperature and pressure
$N_{P_{KL},Qo}$: dosimeter calibration coefficient
k_Q : beam quality correction factor
NT : nominal width of irradiating beam

Normalized $_nC_{a,100}$, mGy/mAs

$$_nC_{\mathrm{a},100} = \frac{C_{\mathrm{a},100}}{P_{\mathrm{It}}}$$

Dosimetry methodology : CT

Calculation of the weighted CTDI, C_w



$$C_{\mathrm{PMMA},100,\mathrm{c}} = \frac{1}{NT}\,\overline{M}_{\mathrm{c}}\,N_{P_{\mathrm{KL}},Q_0}\,k_Q\,k_{\mathrm{TP}}$$

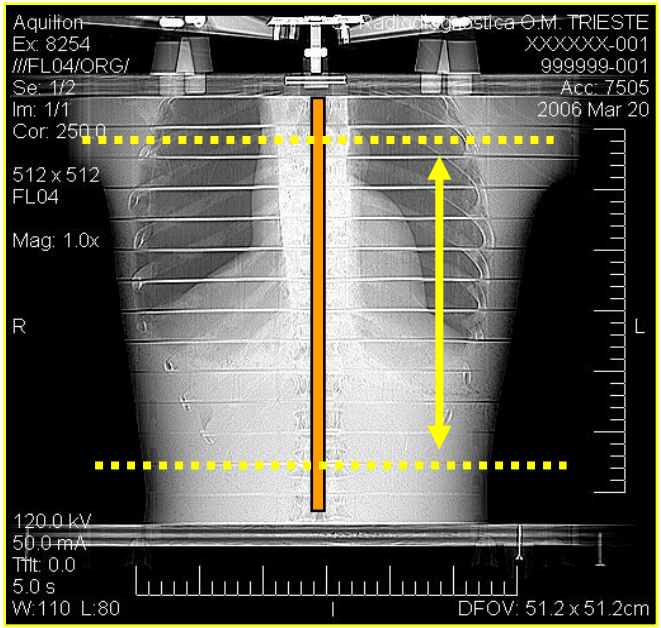
$$C_{\mathrm{PMMA},100,\mathrm{p}} = \frac{1}{NT}\,\overline{M}_{\mathrm{p}}\,N_{P_{\mathrm{KL}},Q_0}\,k_Q\,k_{\mathrm{TP}}$$

$$C_{\mathrm{W}} = \frac{1}{3}\left(C_{\mathrm{PMMA},100,\mathrm{c}} + 2\,C_{\mathrm{PMMA},100,\mathrm{p}}\right)$$

$${}_{\mathrm{n}}C_{\mathrm{W}} = \frac{C_{\mathrm{W}}}{P_{\mathrm{It}}}$$

Dosimetry methodology : CT

- Patient dose index assessed in terms of
  - C_{vol} : CTDI volume (ref. to one "rotation") **mGy**
  - $P_{KL,CT}$: CT Air kerma Length product – DLP (ref to total exam) **mGy cm**
- Derived from phantom measurements & patient scan parameters
- Derived from DICOM / Header data
- **No direct measurements on patients**



- ✓Dose measurements (clinical measurements)
  - Instrumentation
  - Procedures – Dosimetry protocols
- **✓Patient dosimetry**
- ✓Diagnostic Reference Levels (DRL)
  - Local - Regional – National
- ✓Collective Dose - Effective dose

Patient dosimetry

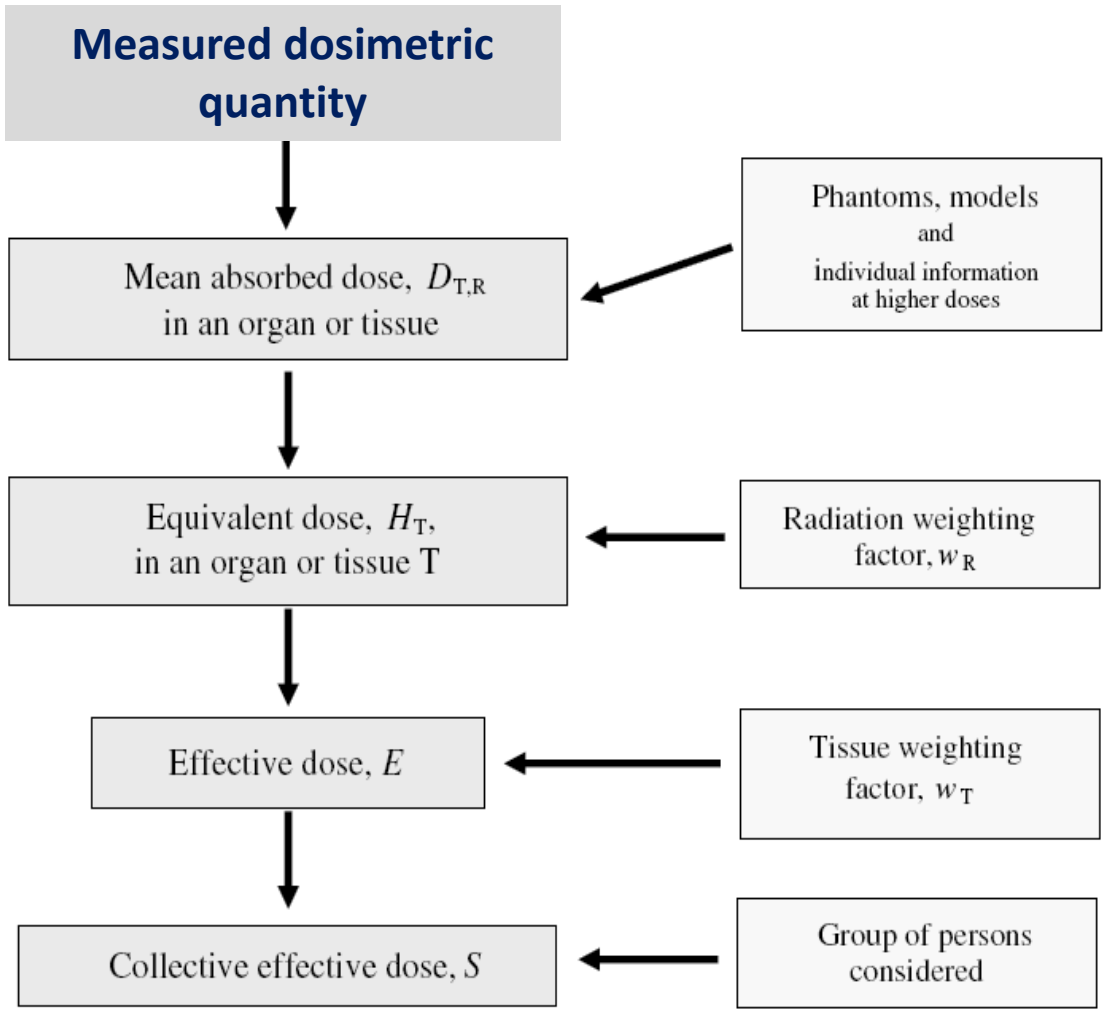


Fig. B.1. System of dose quantities for use in radiological protection.

K_i, K_e, P_{KL}, P_{KA}

Gy, Gy cm, Gy cm^2

Gy

Sv

Sv

man – Sv

Sv/inhabitant(s)

Conversion coefficients for the assessment of organ and tissue doses

In most situations in diagnostic radiology, it is not possible or practicable to measure organ doses directly.

A **conversion coefficient, *c***, relates the dose to an organ or tissue to a readily measured or calculated dosimetric quantity, thus

$$c = \frac{\text{organ or tissue dose}}{\text{measured or calculated quantity}}$$

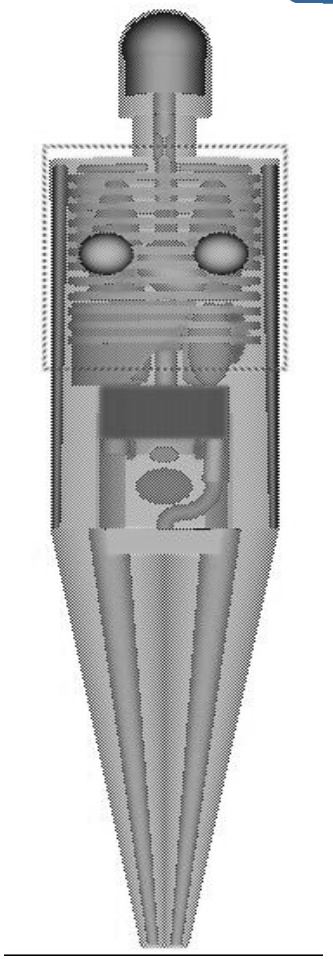
Suffices are added to *c* to indicate the two quantities that are related, for example the coefficient

$$c_{D_T, K_i} = D_T / K_i$$

relates the organ dose, D_T, to the incident air kerma, K_i

Tables of such conversion coefficients are generally produced using **Monte Carlo based computer models**

Two approaches for the simulation of the human body



1st approach : *Mathematical phantom (geometrical phantom)*

Body & organs are constructed as combinations of various geometrical solids.

First phantom was based on ICRP Reference Man.

Cristy phantoms : represent children (1,5,10, 15y)

ADAM and EVA phantoms : GSF male and female phantoms

2nd approach : Voxel phantoms based on the anatomy of individuals

Name	Gender	Age	Type	Mass	Height	Voxel size	No of organs
				kg	mm	mm^3	
Baby	Female	8 weeks	Whole body	4.2	570	2.9	56
Child	Female	7 years	Whole body	21.7	1150	19.0	61
Donna	Female	40 years	Whole body, with standardized GI tract	79	1700	35.2	62
Helga	Female	26 years	From mid thigh upwards	81 (76.8)	1700 (1140)	9.6	62
Frank	Male	48 years	Torso and head	(65.4)	(965)	2.8	60
Golem	Male	38 years	Whole body	68.9	1760	34.6	121
Otoko	Male		Whole body	65	1700	9.6	122
Standardised GI tract	Female		GI Tract			2.0	14
Visible Human	Male	38 years	From knees upwards	(87.8) 103.2	(1250) 1800	4.3	131

*All phantoms are based on **real persons**. Where the mass or height are given in brackets, this denotes the values for the phantom, otherwise the values are for the individual.

Patient dosimetry

Organ dose conversion coefficients per incident air kerma, for chest PA examination; tube voltage: 141 kV; total filtration: 5.7 mm Al

Organ	Organ dose per unit incident air kerma (mGy/(mGy)		
	Voxel Golem	Voxel visible human	Mathematical Adam
Colon	0.09	0.04	0.008
Testes	–	–	–
Liver	0.38	0.30	0.27
Lungs	0.57	0.51	0.79
Pancreas	0.27	0.19	0.32
Red bone marrow	0.26	0.21	0.21
Skeleton	0.40	0.33	0.39
Spleen	0.77	0.52	0.39
Small intestine	0.09	0.04	0.01
Stomach wall	0.30	0.24	0.14
Thyroid	0.28	0.18	0.14
Surface (entrance)	1.27	1.40	1.39
Surface (exit)	0.10	0.07	0.09

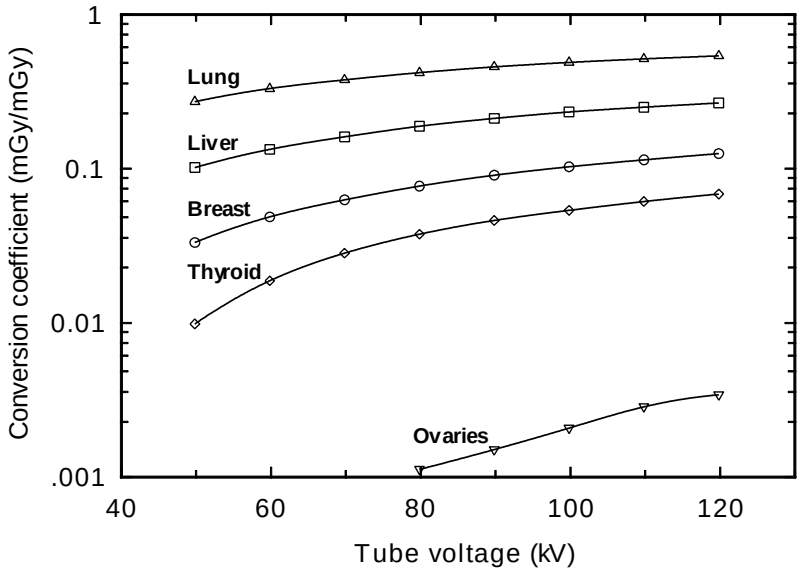
PETOUSSI-HENSS, N., ZANKL, M., FILL, U., REGULLA, D., The GSF family of voxel phantoms, Phys. Med. Biol. **47** (2002) 89-106.

costas.hourdakis@eeae.gr

Patient dosimetry

$$D_T = K_e \cdot c_{D_T, K_e}$$

K_e : measured with TLDs on patients, or calculated from K_i : $K_e = K_i \cdot B$



c_{D_T, K_e}

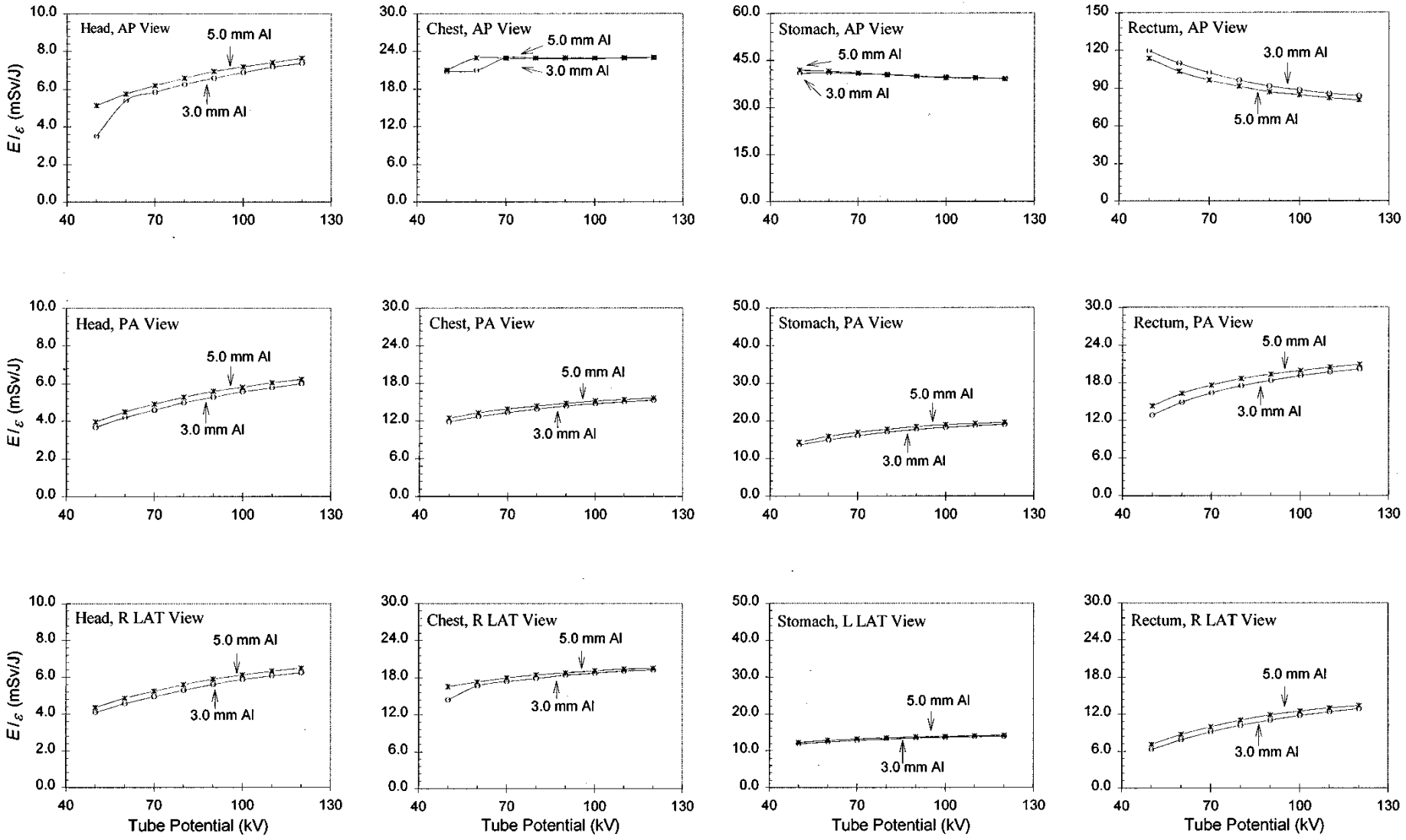
Conversion coefficients, entrance air kerma K_e to organ doses

Example : Chest PA X-ray examination (total filtration of 3 mm Al) : Organ dose conversion coefficients for lung, liver, breast, thyroid and ovaries. n, X ray spectra have.

Data from HART, D., JONES, D.G., WALL, B.F., Normalised Organ Doses for Medical X-Ray Examinations Calculated Using Monte Carlo Techniques, National Radiological Protection Board Rep. NRPB-SR262, Chilton (1994)

Patient dosimetry

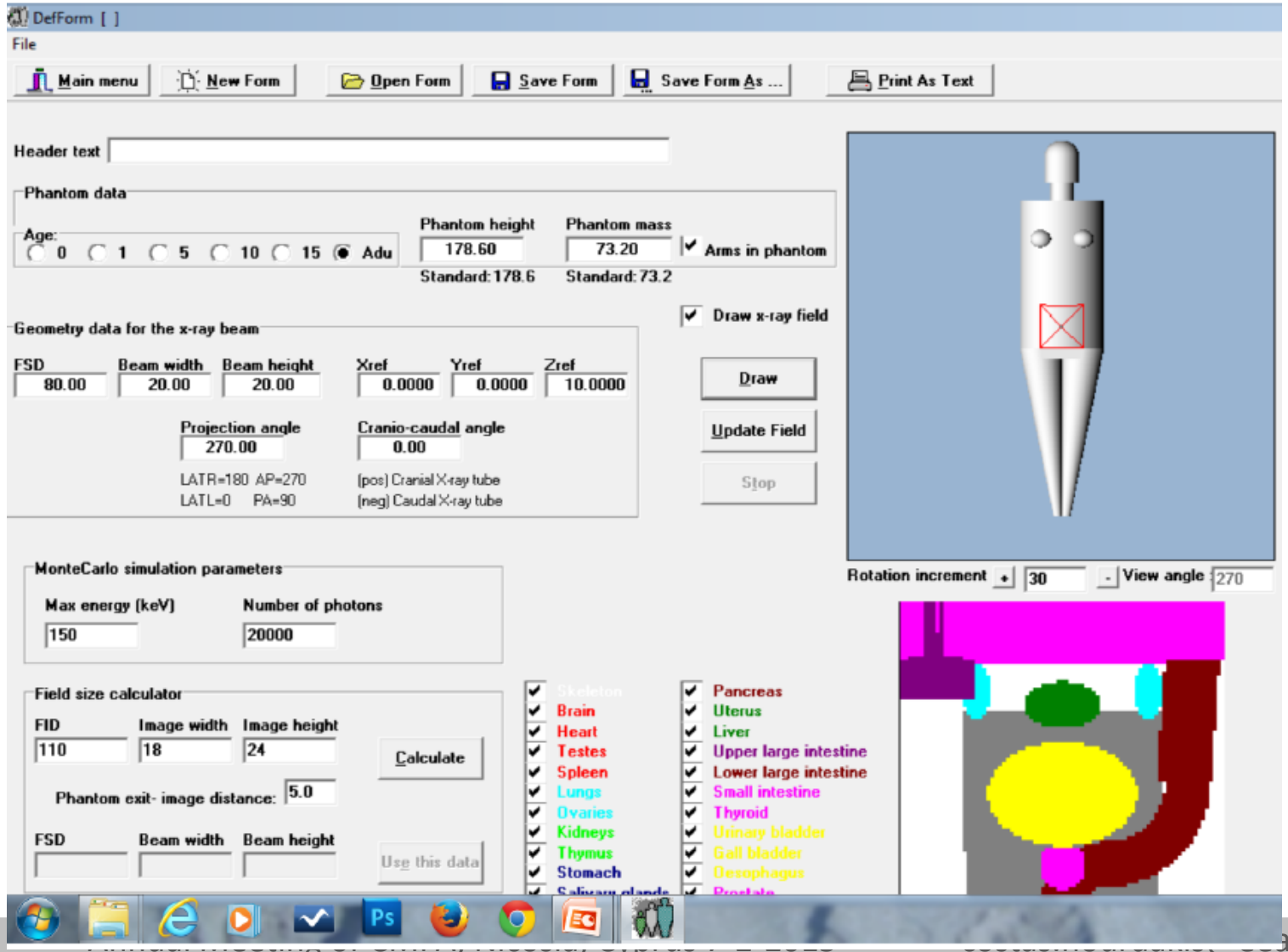
Conversions coefficient E/ε (mSv/J) – Effective dose from imparted energy, ε



W. Huda and N. A. Gkanatsios, Dose and energy in diagnostic radiology, Medical Physics, Vol. 24, No. 8, August 1997

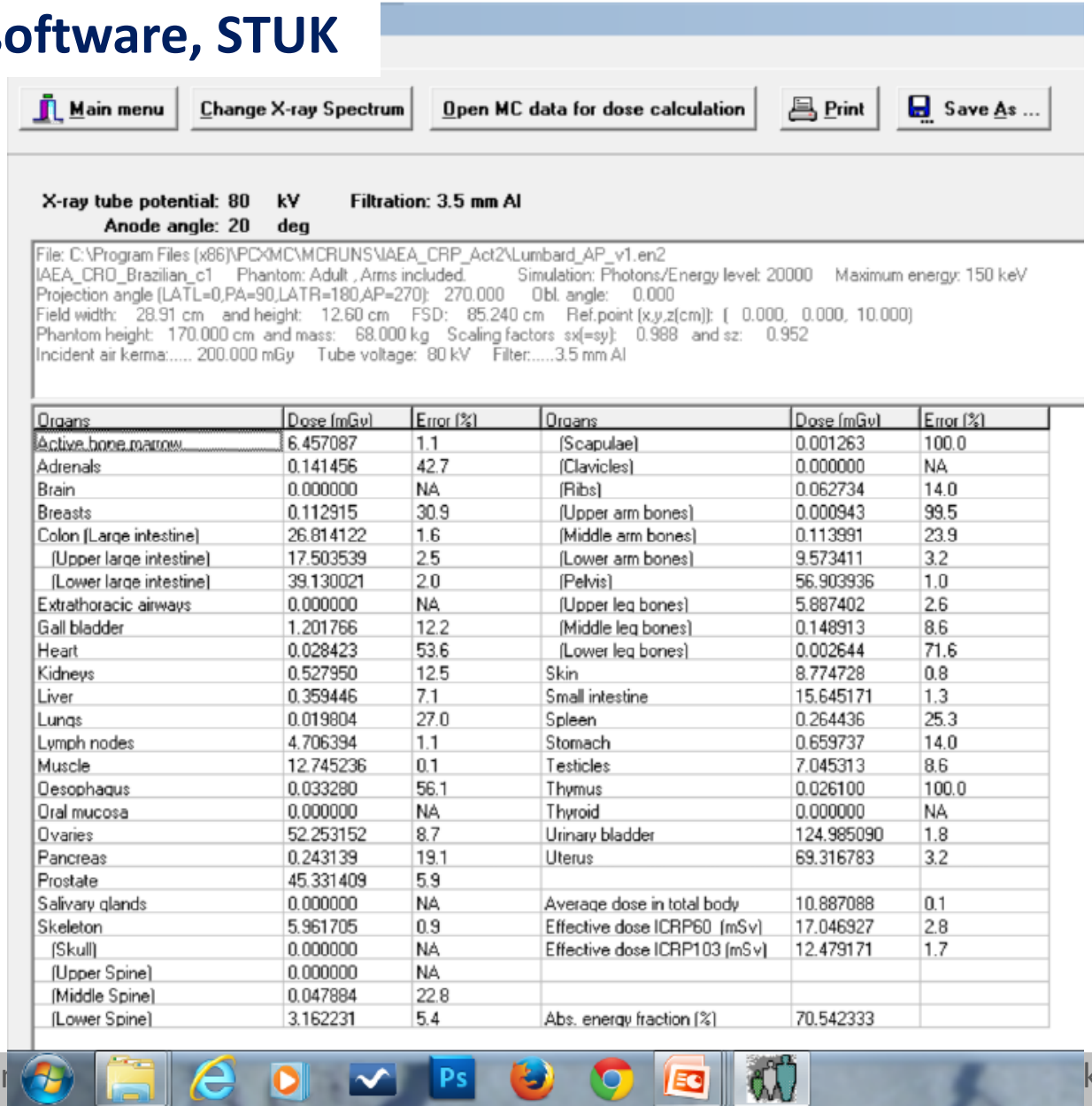
Patient dosimetry

PCXMC software, STUK



Patient dosimetry

PCXMC software, STUK



Organs	Dose (mGy)	Error (%)	Organs	Dose (mGy)	Error (%)
Active bone marrow	6.457087	1.1	(Scapulae)	0.001263	100.0
Adrenals	0.141456	42.7	(Clavicles)	0.000000	NA
Brain	0.000000	NA	(Ribs)	0.062734	14.0
Breasts	0.112915	30.9	(Upper arm bones)	0.000943	99.5
Colon (Large intestine)	26.814122	1.6	(Middle arm bones)	0.113991	23.9
(Upper large intestine)	17.503539	2.5	(Lower arm bones)	9.573411	3.2
(Lower large intestine)	39.130021	2.0	(Pelvis)	56.903936	1.0
Extrathoracic airways	0.000000	NA	(Upper leg bones)	5.887402	2.6
Gall bladder	1.201766	12.2	(Middle leg bones)	0.148913	8.6
Heart	0.028423	53.6	(Lower leg bones)	0.002644	71.6
Kidneys	0.527950	12.5	Skin	8.774728	0.8
Liver	0.359446	7.1	Small intestine	15.645171	1.3
Lungs	0.019804	27.0	Spleen	0.264436	25.3
Lymph nodes	4.706394	1.1	Stomach	0.659737	14.0
Muscle	12.745236	0.1	Testicles	7.045313	8.6
Oesophagus	0.033280	56.1	Thymus	0.026100	100.0
Oral mucosa	0.000000	NA	Thyroid	0.000000	NA
Ovaries	52.253152	8.7	Urinary bladder	124.985090	1.8
Pancreas	0.243139	19.1	Uterus	69.316783	3.2
Prostate	45.331409	5.9			
Salivary glands	0.000000	NA	Average dose in total body	10.887088	0.1
Skeleton	5.961705	0.9	Effective dose ICRP60 (mSv)	17.046927	2.8
(Skull)	0.000000	NA	Effective dose ICRP103 (mSv)	12.479171	1.7
(Upper Spine)	0.000000	NA			
(Middle Spine)	0.047884	22.8			
(Lower Spine)	3.162231	5.4	Abs. energy fraction (%)	70.542333	

Dosimetry methodology : Mammography

K_i **Incident air kerma**

K_e Entrance surface air kerma

} measured

Mean glandular dose, D_G , is the risk related quantity therefore is the primary quantity of interest

Dosimetry methodology : Mammography

Calculation of mean glandular dose to a 50 mm standard breast of 50% glandularity (IAEA protocol)

$$D_{G\,50} = K_i \cdot c_{DG50,\,Ki,PMMA} \cdot s$$

HVL (mm Al)	$c_{DG50,Ki,PMMA}$ (mGy/mGy)
0.25	0.149
0.30	0.177
0.35	0.202
0.40	0.223
0.45	0.248
0.50	0.276
0.55	0.304
0.60	0.326
0.65	0.349

* Data taken from Ref. [8.2].

Conversion coefficient $c_{DG50,\ Ki,PMMA}$ used to calculate the mean glandular dose to a 50 mm standard breast of 50% glandularity from the incident air kerma for 45 mm PMMA phantom

Target/filter combination	*s* factor
Mo/Mo	1.000
Mo/Rh	1.017
Rh/Rh	1.061
Rh/Al	1.044
W/Rh	1.042

* Data taken from Dance et al. [8.20].

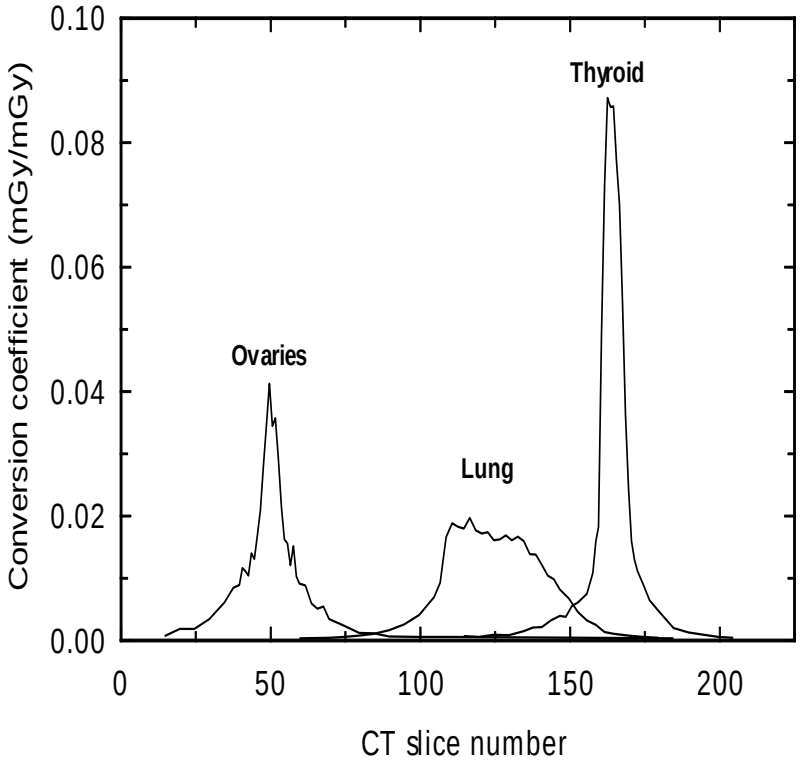
Value of s-Factor for different mammographic target / filter combinations

Dosimetry methodology : Mammography

$$D_G = D_{G\,50} \cdot c_{D_G,\, D_{G\,50}}$$

HVL	Breast Thick.	Breast glandularity				
mm Al	mm	0.1%	25%	50%	75%	100%
0.30	20	1.130	1.059	1.000	0.938	0.885
	30	1.206	1.098	1.000	0.915	0.836
	40	1.253	1.120	1.000	0.898	0.808
	50	1.282	1.127	1.000	0.886	0.794
	60	1.303	1.135	1.000	0.882	0.785
	70	1.317	1.142	1.000	0.881	0.784
	80	1.325	1.143	1.000	0.879	0.780
	90	1.328	1.145	1.000	0.879	0.780
	100	1.329	1.147	1.000	0.880	0.780
	110	1.328	1.143	1.000	0.879	0.779

Patient dosimetry



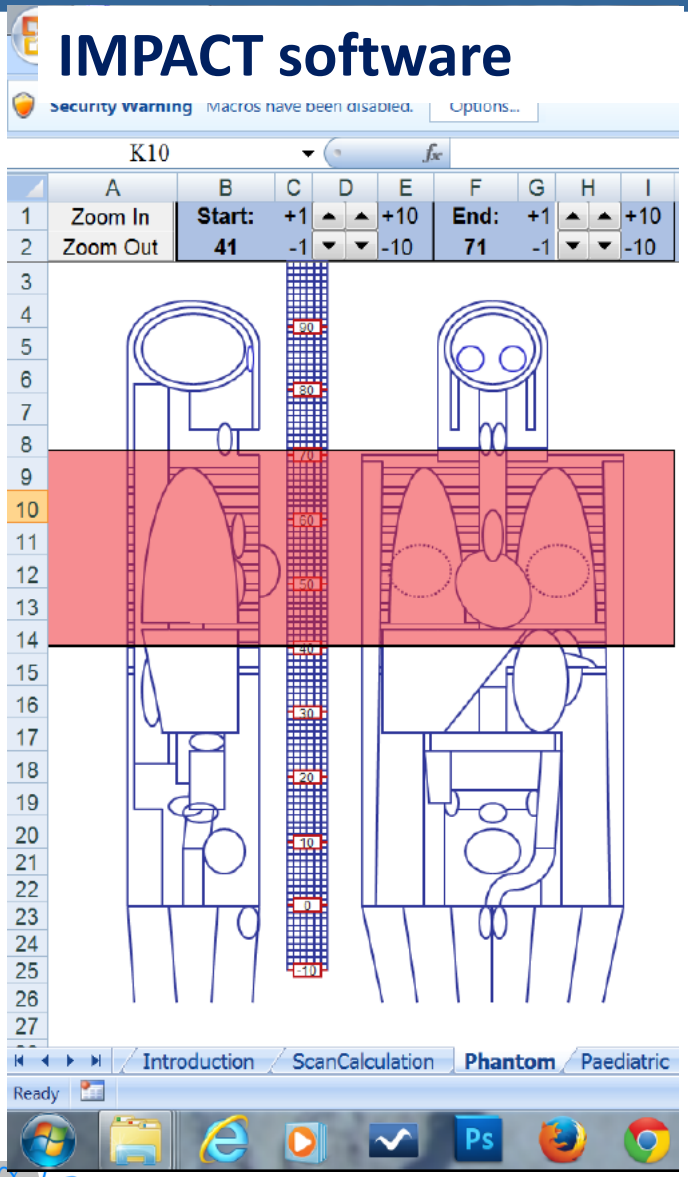
CT

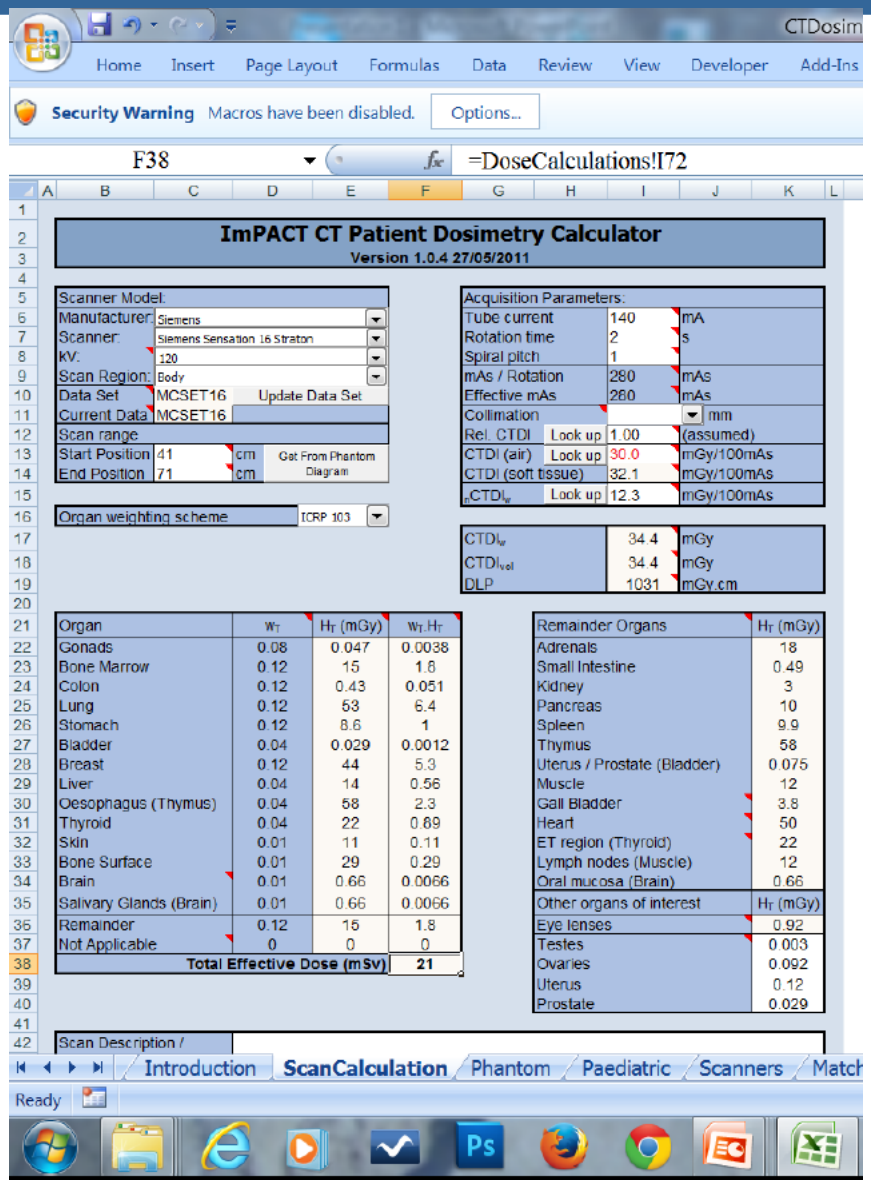
Variation along the length of the patient of organ dose conversion coefficients per 5 mm CT slice for ovaries, lung and thyroid for a particular CT scanner.

[JONES, D.G., SHRIMPTON, P.C., Survey of CT Practice in the UK. Part 3: Normalised Organ Doses Calculated Using Monte Carlo Techniques, National Radiological Protection Board Rep. NRPB-R250, Chilton (1991)]

Patient dosimetry

IMPACT software





Patient dosimetry

Examination Coliche **Mode:** Slice scanning
using scanner: Philips **Model:** Tomoscan 1998
Monte Carlo Dose Data derived from: Philips Tomoscan AV

Scan plans:
Comment: COLICHE 3 IN 5
kV:120 **mAs:**250,00 **Slices:**60 **CTDI (mGy/mAs):** 0,1678
Slice Width (mm):3,0 **Table feed per slice(mm):** 5,0 **nCTDIw (Head) (μGy/mAs):** 127,7 +/- 1,9 %
Scan Start (cm): 35,0 **Scan End (cm):** 5,2 **nCTDIw (Body) (μGy/mAs):** 67,1 +/- 1,9 %

Prime Organs	Equivalent Dose	Error
Lungs	0,28 mGy	3%
Stomach Wall	6,8 mGy	2%
Urinary Bladder Wall	11 mGy	2%
Breasts	0,10 mGy	6%
Liver	4,8 mGy	2%
Esophagus	0,14 mGy	10%
Thyroid	2,6 μGy	10%
Skin	2,7 mGy	1%
Bone Surface	4,5 mGy	2%
Red bone marrow	4,0 mGy	2%
Testes (Gonads)	0,95 mGy	4%
Ovaries (Gonads)	11 mGy	2%
LLI Wall (Colon)	8,9 mGy	2%

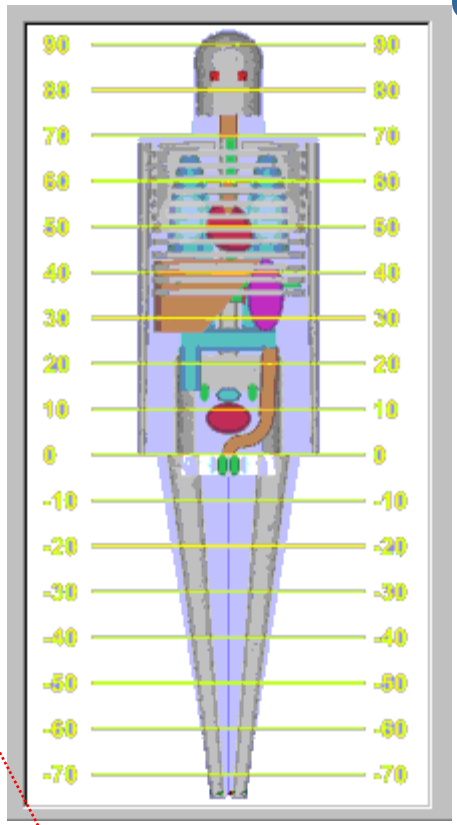
Other Organs	Equivalent Dose	Error
Pelvis	26 mGy	2%
Spine	6,2 mGy	2%
Skull Cranium	0 mGy	0%
Skull Facial	1,9 μGy	50%
Rib Cage	1,5 mGy	2%
Clavicles	23 μGy	40%
Eye Lenses	0 mGy	0%
Gall Bladder Wall	10 mGy	2%
Heart	0,30 mGy	5%

Remainder Organs	Equivalent Dose	Error
Muscle	3,7 mGy	1%
Adrenals	1,5 mGy	7%
Brain	0 mGy	0%
Small Intestine	12 mGy	2%
ULI Wall	12 mGy	2%
Kidneys	11 mGy	2%
Pancreas	3,4 mGy	3%
Spleen	4,6 mGy	2%
Thymus	92 μGy	30%
Uterus	11 mGy	2%

Marrow Doses	Equivalent Dose	Error
Pelvis	9,6 mGy	2%
Spine	2,3 mGy	2%
Skull Cranium+Facial	0,17 μGy	50%
Rib cage	0,48 mGy	2%
Clavicles	6,5 μGy	40%
Scapulae	33 μGy	10%
Upper Part of Legs	0,36 mGy	2%
Upper Part of Arms	21 μGy	10%

Effective Dose (ICRP 60) 4,9 mSv +/- 2%

DLP (head phantom) 0,57 Gy cm +/- 2%
DLP (body phantom) 0,30 Gy cm +/- 2%



C_w = 17 mGy (body)

C_{vol} = 10 mGy (body)

- ✓Dose measurements (clinical measurements)
  - Instrumentation
  - Procedures – Dosimetry protocols
- ✓Patient dosimetry
- **✓Diagnostic Reference Levels (DRL)**
  - Local - Regional – National
- ✓Collective Dose - Effective dose

WHY DO WE NEED DRL :

Image quality – diagnostic information and DOSE

Lack of optimization & justification usually leads to inappropriate patient dosed

- Inappropriate technique factors, e.g. too low kVp in chest
- Images routinely shot too dark
- Inappropriate film chemistry (e.g., to little regeneration)
- Not properly adjustment of digital system components
- images produced can even be of low diagnostic quality

Higher dose may result in better quality images, <u>when justified and optimized</u>

- Better spatial resolution, better S/N, better low contrast detectability

… somehow as rules of equality between patients

What are DRLs

- ✓ a basis for the review of dose values applied
- ✓ dose values not exceeded on regular base, provided good radiographic practice is applied
  - for standard patients
  - undergoing standard diagnostic and interventional procedures
- ✓ DRLs serve as a means to identify situations where patient doses are unusually high

What are DRLs NOT

- DRLs are no limiting (maximum) values or dose limits
- Are NOT Static → DRLs require continuous updating
- Do not applied to non – standard patients
- DRLs do not provide a guidance on the reason or a remedy in case they are exceeded. **Instead: exceeding of DRLs triggers investigation**
- They do NOT stand alone : They are connected to
  - image quality is appropriate
  - the examination is performed at an optimized dose level
  - should be determined at national – regional – local level

DRL

- ✓ Should defined for each examination technique (or the most common)
- ✓ Dosimetry indicators :
  - Incident air kerma or entrance surface air kerma (general radiography)
  - Incident air kerma for mammography
  - P_{KA} for fluoroscopy
  - $C_W(CTDI_w)$, $C_{VOL}(CTDI_{vol})$, $P_{KL,CT}(DLP)$, or DLP for CT
- ✓ Different DRL for different technologies (?) (DR, CR, conventional films)
- ✓ Sufficient number of patients : 10 (preferably 20) per x-ray system, per clinic, per examination / technique
- ✓ Standard size patient (weight, height)
- ✓ Data should be representative for all clinics, country areas, etc

Radiography

Calculated incident air kerma and entrance surface air kerma

Tube focus to table top distance (d_{FTD}): _____ mm Distance, d, of dosimeter from tube focus: _____ mm

Patient	Weight (kg)	Tube voltage (kV)	Tube loading (mA·s)	Patient thickness (t_P) (mm)	Field size (mm × mm)	Backscatter factor (B)	Tube output, $Y(d)$, at distance d [a] (mGy/(mA·s))	Incident air kerma (K_i)[b] (mGy)	Entrance surface air kerma (K_e)[c] (mGy)

Fluoroscopy

$\dot{K}_e$ Phantom: Fluoro 2

4. Dosimeter reading and calculation of entrance surface air kerma rate

Selected option	Tube voltage (kV)	Tube current (mA)	Filtration (mm Al)	Manual or automatic mode setting[a]	Field size (mm × mm)	Dosimeter readings ($\dot{M}_1$, $\dot{M}_2$, $\dot{M}_3$) (mGy/min)	Mean dosimeter reading ($\bar{\dot{M}}$) (mGy/min)	k_Q	Entrance surface air kerma rate ($\dot{K}_e$)[b] (mGy/min)

Mammography

2 Collected data and calculation of mean glandular dose

L/R breast	Projection	Target/ filter	Tube voltage (kV)	Tube loading ($P_{h,put}$) (mA·s)	Breast thickness (mm)	Distance (d_P) (mm)	Tube output at reference point (Y_{ref})[a] (mGy·mA^{-1}·s^{-1})	Incident air kerma (K_i)[b] (mGy)	HVL[c] (mm Al)	s-factor	Conversion coefficient ($c_{D(150),K_i}$)[d] (mGy/mGy)	Conversion coefficient ($c_{D_{G_R},D(150)}$)[d] (mGy/mGy)	Mean glandular dose (D_G)[e] (mGy)

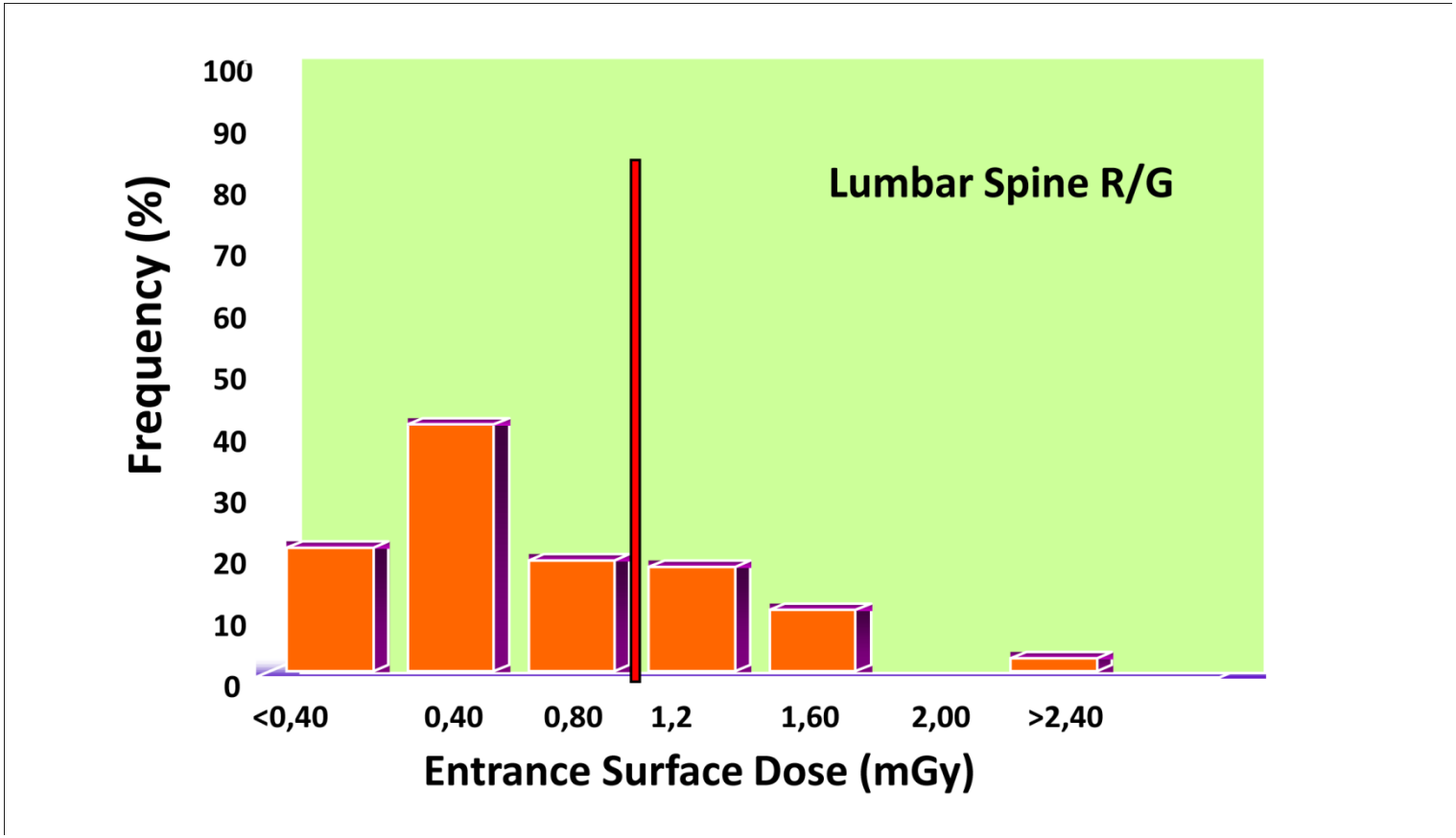
CT

Phantom: CT 3

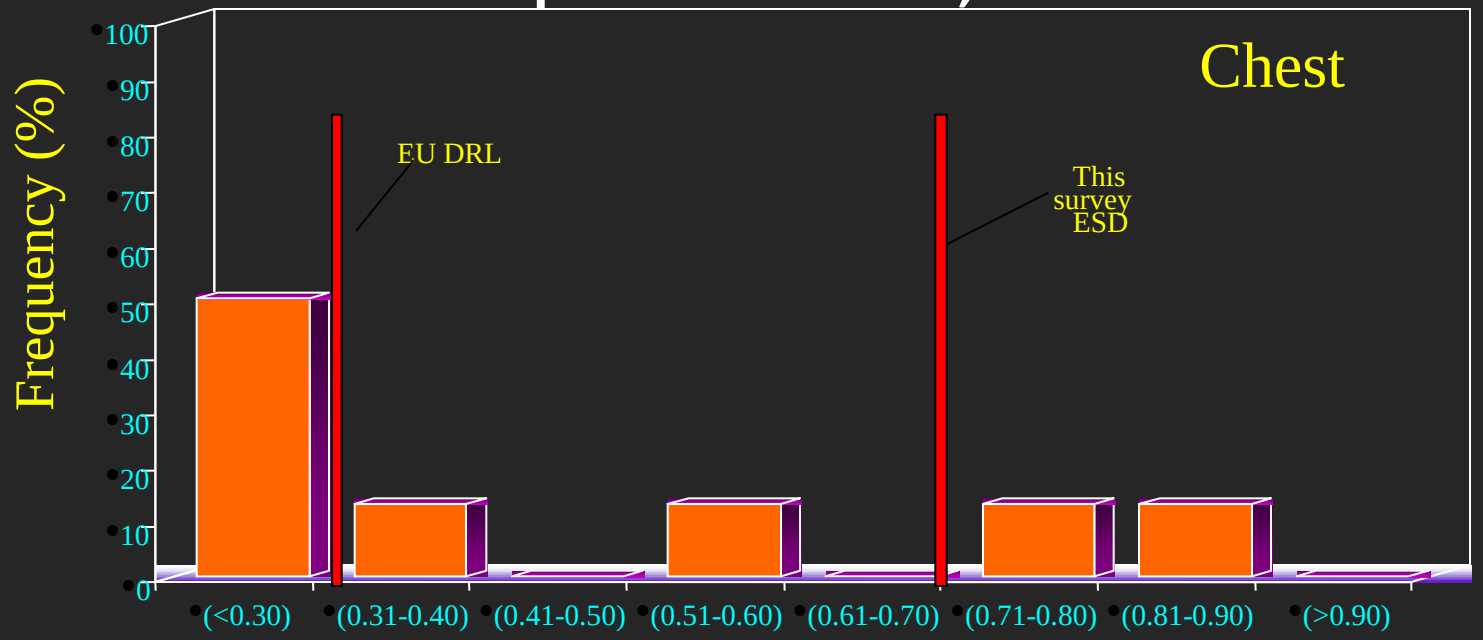
4. CT air kerma indices $C_{PMMA,100,c}$, $C_{PPMMA,100,p}$ and C_w for the standard phantom **Head/body:** _____

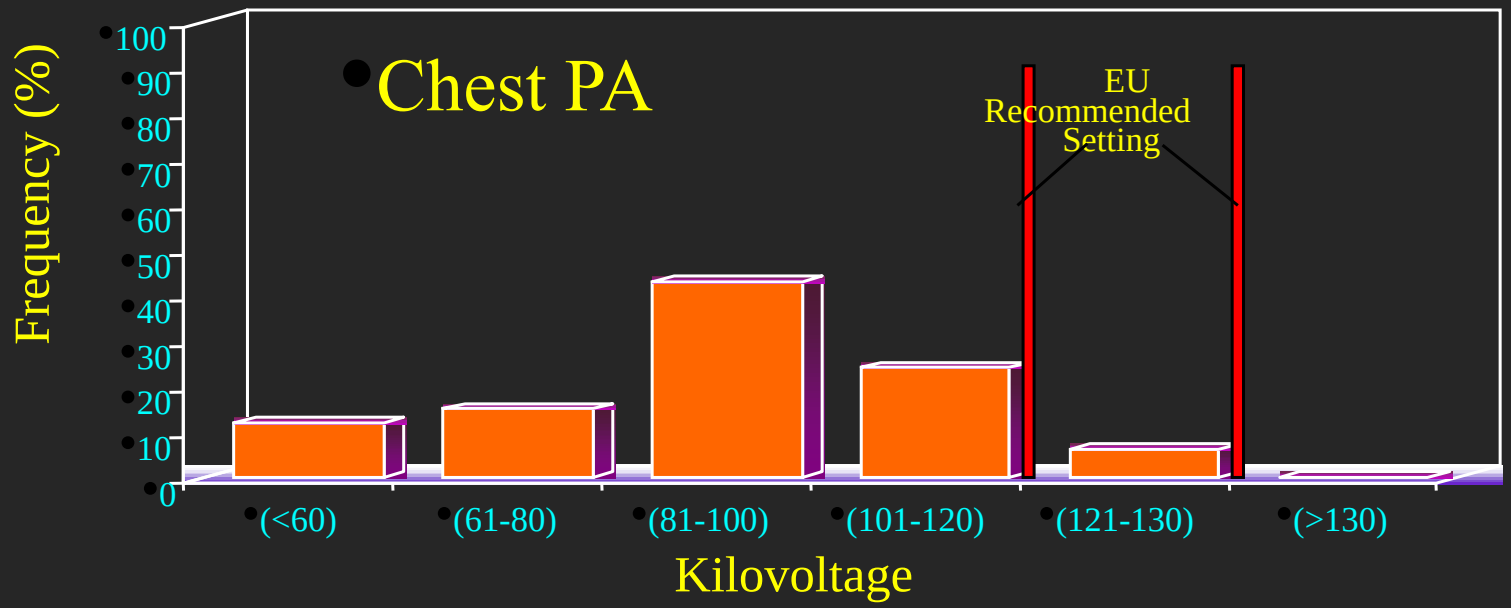
Scanner settings (tube voltage, beam filter, head/body mode, etc.)	Nominal slice thickness (T) (mm)	Number of slices (N)	Tube loading (P_h) (mA·s)	Position	Dosimeter readings (M_1, M_2, M_3)	Mean $\bar{M}_c$ or $\bar{M}_p$	Calculated value of $C_{PMMA,100,c}$ (mGy)	Calculated value of $C_{PMMA,100,p}$ (mGy)	Calculated value of C_w (mGy)	Calculated value of ${}_nC_w$ (mGy·mA^{-1}·s^{-1})
				C						
				P1						
				P2						
				P3						
				P4						
				C						
				P1						

DRL


Lumbar Spine R/G
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
<0,40
0,40
0,80
1,2
1,60
2,00
>2,40
Entrance Surface Dose (mGy)

Example from Greece, 1999





Pediatric DRLs

- DRLs need to be defined for different groups
  - **By size** (height, weight): better correlation, but hard to apply
  - **By age**: easier to use in clinical practise, and therefore recommended
  - **Age bands**: variation of dose within clinics is larger than between smaller and older children → children grouped into age bands, average doses are then compared to dose reference corresponding to upper limit of the age band (e.g., 5 to 10 year olds to guidance level corresponding to a typical 10 year old, etc.)

- Typically age bands: newborns (<1m), 1m-1y, 1 to 5, 5 to 10, 10 to 15

Pediatric DRLs

Paediatrics

Usually, grouping based on age :

0 -1m, 1m – 1y, 1y - 5y, 5y - 10y, 10y – 15y

More appropriate based on body mass index (i.e. weight – height)

DRL

For comparisons in the hospital ...

- Selected sample that best represents the population studied
- Modality

For regional or country comparisons

- Selected sample that best represents the population studied.
- Modality
- Geographical
- Heath care level

DRL

Greek paradigm for reducing the uncertainties on data collection

Grouping the clinics / hospital according to their

✓**Infrastructure**

- X1 : labs operate R/G, Mammo, Dental
- X2 : labs : X1 + CT
- X3 : labs : X2 + interventional or complex or large number (>15) of X-ray units

✓**Health care level**

- Pr – Lab : private operate outside clinic (X1 or X2)
- Pr – Clin : private clinic (X3 or X2)
- Pub Hosp : Public large hospitals (X3 or X2)
- Pub HC : Public health care centers operating at regional level (X1)
- Pub Ins : Public Insurance centers (X1 or X2)

✓**Geographical location**

- Athens (capital) region
- Large cities
- Countryside

Data collection from 30% of each group – combination (45)

- **Patient data (20 patients for each examination-procedure)**
- **Dosimetry**

DRL

ΕΦΗΜΕΡΙΣ ΤΗΣ ΚΥΒΕΡΝΗΣΕΩΣ
ΤΗΣ ΕΛΛΗΝΙΚΗΣ ΔΗΜΟΚΡΑΤΙΑΣ
ΤΕΥΧΟΣ ΔΕΥΤΕΡΟ Αρ. Φύλλου 3176
26 Νοεμβρίου 2014

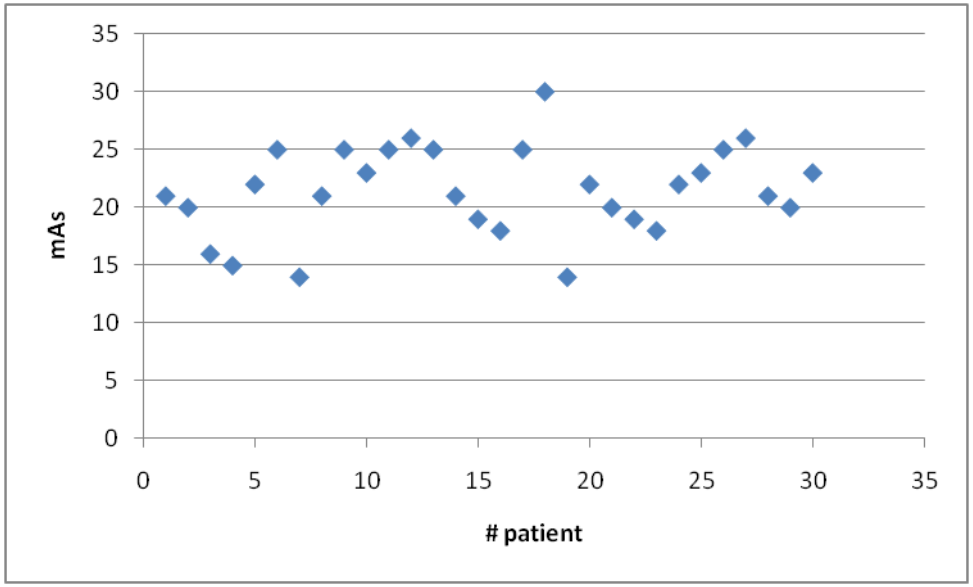
Ακτινογραφικές εξετάσεις	ESAK (mGy)
Κεφαλής ΟΠ/ΠΟ	3,7
Κεφαλής Πλάγια	2,8
Θώρακος ΟΠ	0,35
Θώρακος Πλάγια	1,35
Αυχενικής Μοίρας Σπονδυλικής Στήλης	1,75
Οσφυϊκής Μοίρας Σπονδυλικής Στήλης (ΠΟ)	7,0
Οσφυϊκής Μοίρας Σπονδυλικής Στήλης (Πλάγια)	16,0
Λεκάνης-Ισχύων	6,0
ΝΟΚ	6,5

Εξετάσεις Αξονικής Τομογραφίας	CTDIvol (mGy)	DLP
Κεφαλής	67	1055
Σπλαχνικό κρανίο	52	605
Έσω ους	63	355
Θώρακος	14	480
Άνω/κάτω κοιλίας	16	760
Θώρακος και Άνω/κάτω κοιλίας	17	1020
Οσφυϊκής Μοίρας Σπονδυλικής	35	725

Επεμβατική Καρδιολογία	Συνολικός χρόνος ακτινοσκόπησης (min)	Συνολικό γινόμενο Kerma-επιφάνειας - KAP (Gycmz)
Στεφανιογραφία	6	55
Αγγειοπλαστική στεφανιαίας αρτηρίας[1]	18	130
Τοποθέτηση βηματοδότη	7	35
Κατάλυση με ραδιοσυχνότητες (RF ablation)	40	145
Ακτινοσκοπικός ρυθμός δόσης εισόδου σε ομοίωμα[2]	29 mGy/min (για οπτικό πεδίο ενισχυτή εικόνας (FOV), 20-25cm)	
Δόση εισόδου ανά λήψη - frame (CINE) σε ομοίωμα[2]	0,23 mGy/fr (20-25cm FoV)	

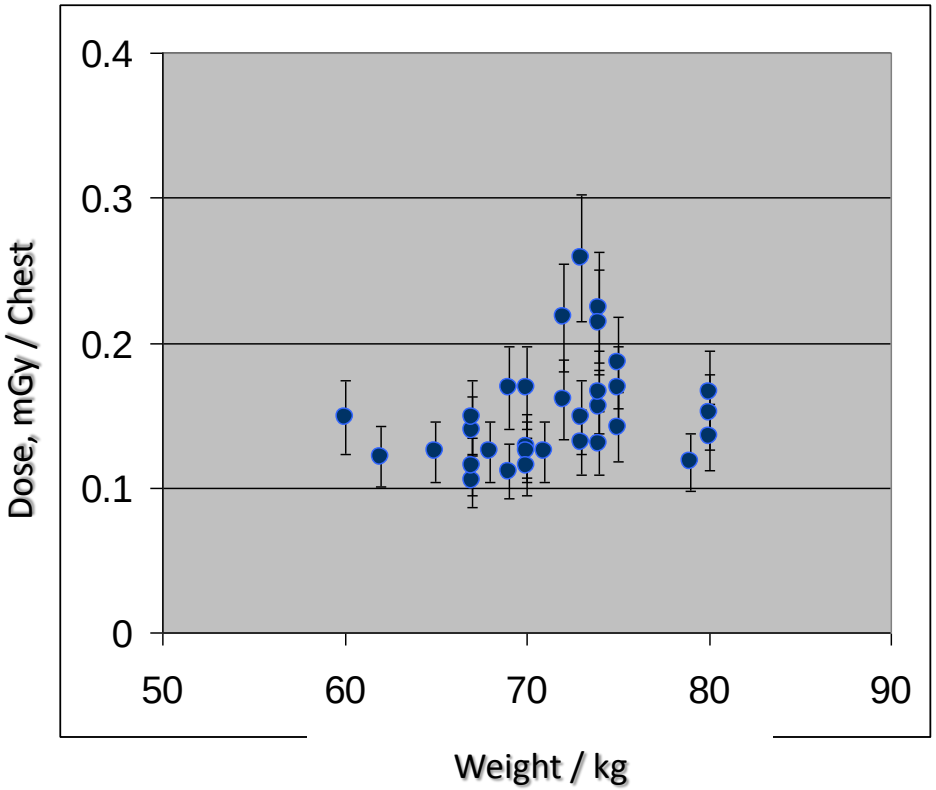
Οδοντιατρικές ακτινογραφικές εξετάσεις	Ki (mGy)	
	Απεικόνιση με φιλμ	Ψηφιακή απεικόνιση
Άνω Γομφίοι	3,70	1,20
Κάτω τομείς	2,35	0,65

Uncertainty due to exposure settings of patients (mAs) @ same unit



Mean	**21.47**	**mAs**
SD	**3.82**	**mAs**
s	**0.70**	**mAs**
u %	**3.25%**	

Dose to an average patient – Comparisons : Uncertainties



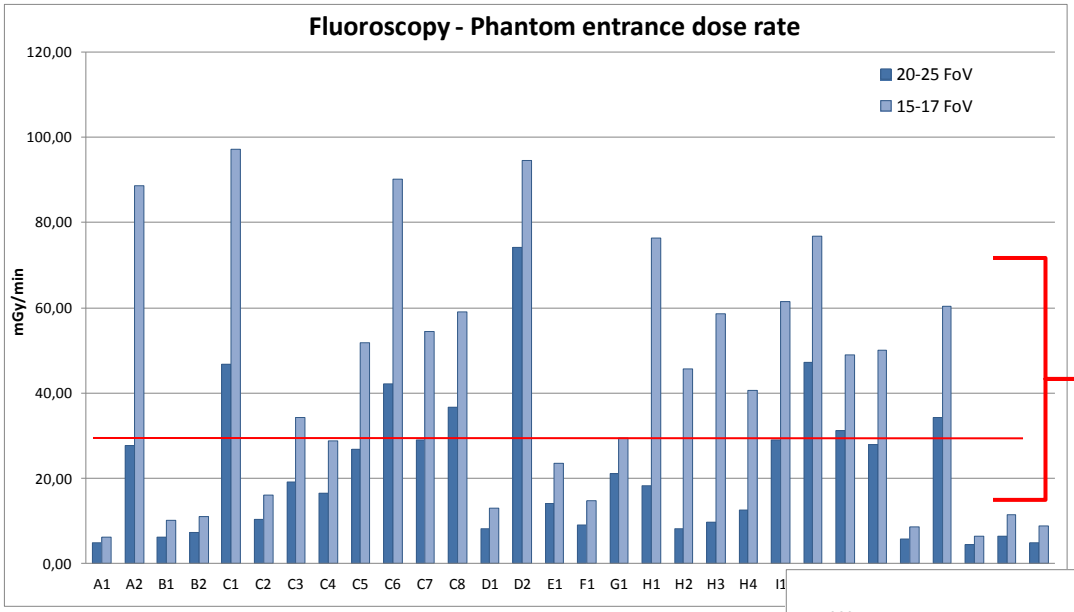
Peter Hamolka, Vienna Hosp, 2009

Scatter of data / number of patients

combined uncertainty: 10% (k=1)

DRL

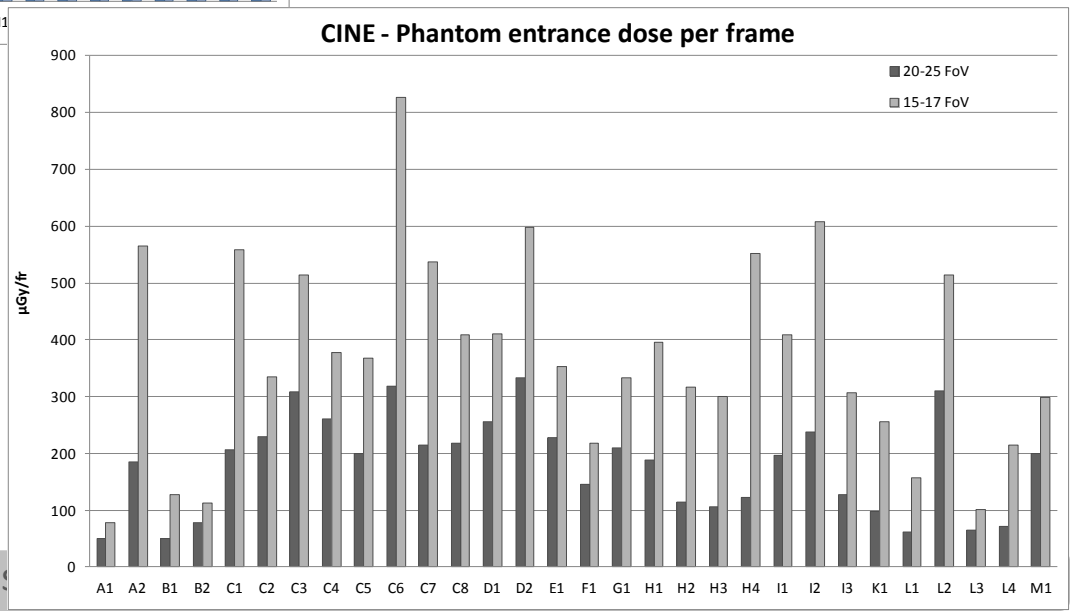
Distributions of patient data (paradigm from Greek hospitals)



Range : ~ 65 mGy/ min

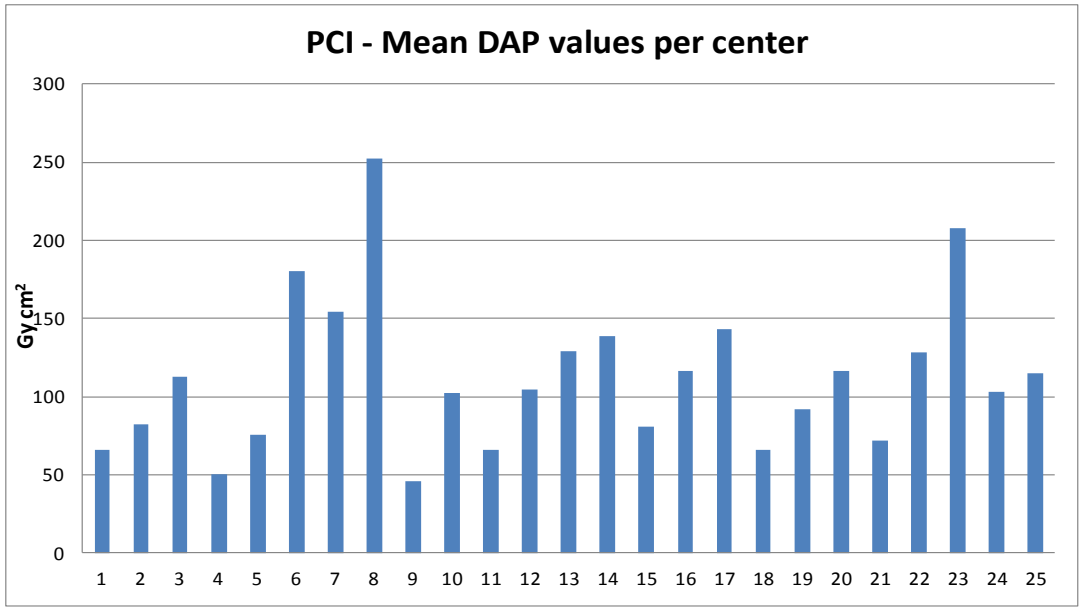
u = 24% (k=1)

Distributions of patient data in Greek hospitals



DRL

Distributions of patient data (paradigm from Greek hospitals)



Range : ~ 200 Gy cm^2

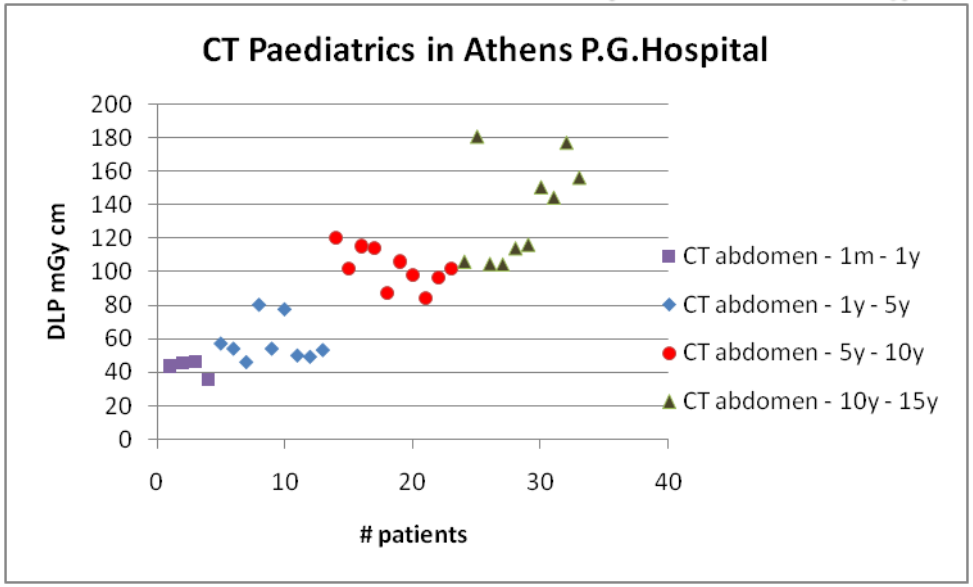
u= 25 % (k=1)

Mean DAP values per hospital for Percutaneous Coronary Intervention

Distributions of patient data in Greek hospitals

DRL

Distributions of patient data (paradigm from Greek hospitals)

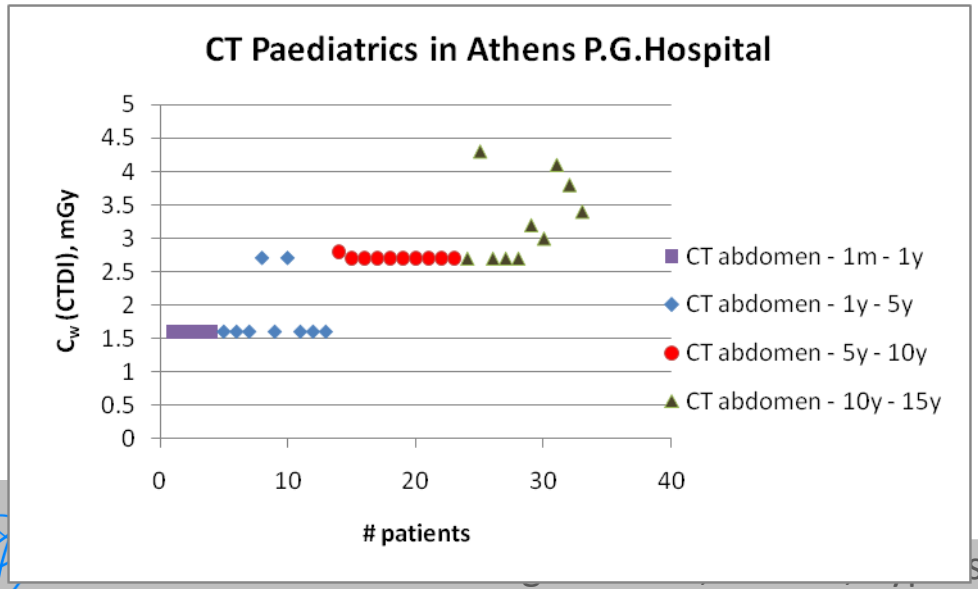


Pediatric DRLs

DLP

1m - 1y: 42.7 ± 2.4 mGy cm
1y - 5y: 58.2 ± 4.1 mGy cm
5y - 10y: 102.8 ± 3.7 mGy cm
10y - 15y: 135.6 ± 9.5 mGy cm

u= 5 – 10 % (k=1)



C_w

1m - 1y: 1.60 ± -- mGy
1y - 5y: 1.84 ± 0.16 mGy
5y - 10y: 2.71 ± 0.01 mGy
10y - 15y: 3.26 ± 0.20 mGy

DRL

Distributions of patient data (paradigm from Greek hospitals)

Table 4. Summary of $CTDI_{vol}$ and DLP results for the selected examinations.

Exam	$CTDI_{vol}$ (mGy)							DLP (mGy cm)						
	Mean	Min	Max	First quartile	Median	SD	Third quartile	Mean	Min	Max	First quartile	Median	SD	Third quartile
Head	60.7	21.7	172.6	49.9	59.4	19.7	66.7	909	301	2972	729	854	326	1053
Sinuses	38.9	10.6	100.0	22.9	37.2	20.0	52.1	473	86	1160	269	440	257	607
Inner ear	59.4	17.3	291.0	35.8	53.3	45.1	63.5	372	95	1601	226	301	295	359
Chest	12.1	4.5	40.5	8.1	11.1	5.5	14.4	395	158	1297	272	375	178	481
Chest–abdomen–pelvis	13.8	5.6	26.2	10.8	13.4	5.2	16.8	834	335	1714	593	802	333	1022
Abdomen–pelvis	13.9	5.0	38.6	10.6	12.9	6.0	16.3	628	230	1735	468	589	263	758
Lumbar spine	28.2	9.3	80.2	18.5	22.7	14.1	35.2	646	144	1871	444	552	331	723

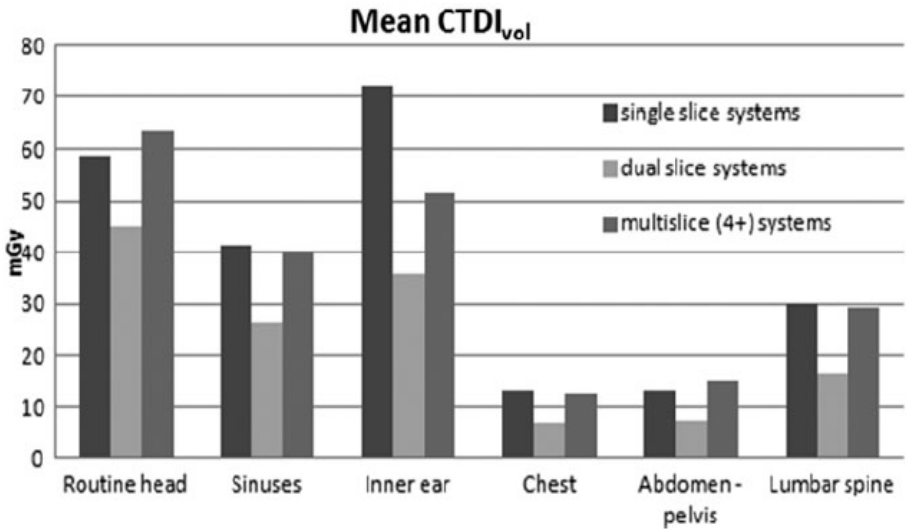


Figure 3. Mean $CTDI_{vol}$ values by scanner group according to the number of simultaneously acquired slices.

Routine Head
#1992 patients
u = 0.7% (k=1)

u of CTDIvol = 4.6% (k=1)

u combined = 4.7% (k=1)

Simantirakis G et al. Radiation Prot. Dosimetry (2-June-2014), pp 1-6

- ✓Dose measurements (clinical measurements)
  - Instrumentation
  - Procedures – Dosimetry protocols
- ✓Patient dosimetry
- ✓Diagnostic Reference Levels (DRL)
  - Local - Regional – National
- **✓Collective Dose - Effective dose**

Collective dose, S

$$S = \sum_{procedure} \sum_{patient} E^{mean}_{procedure} \cdot N^{patient}_{procedure}$$

Ε ΤΑΕ 04 ΕΚΔ01/ΑΝΑ802

Αριθμός εξετάσεων σε ΑΚΤΙΝΟΛΟΓΙΚΑ ΕΡΓΑΣΤΗΡΙΑ

Επωνυμία Εργαστηρίου .....

Έτος :				
	Περιοχή	**Εξέταση**	**Αριθμός λήψεων**	**Αριθμός εξετάσεων**
ΑΚΤΙΝΟΓΡΑΦΗΣΗ	Κρανίο	Κρανίο F ή P, Ρινικό οστό, Ιγμορείων		
	Θώρακας	Θώρακος F ή P , Τηλεκαρδίας		
	Κοιλία - Λεκάνη	Κοιλίας (όρθια ή ύπτια θέση), ΝΟΚ		
		Λεκάνης – Ισχίων F ή P		
	Σπονδυλική Στήλη	ΑΜΣΣ F ή P		
		ΟΜΣΣ F ή P		
	Άκρα	Άνω Άκρα F ή P [1]		
		Κάτω Άκρα F ή P [2]		
	Λοιπές ακτινογραφίες			
ΜΑΣΤΟΓΡΑΦΙΑ		Μαστογραφία		
		Τομοσύνθεση		
ΟΔΟΝΤΙΑΤΡΙΚΕΣ		Πανοραμική		
		Κεφαλομετρική		
		Τομογραφικό CBCT		
			Αριθμός εξετάσεων	
		Πυελογραφία		
ΑΚΤΙΝΟ-ΣΚΟΠΗΣΗ		Βαριούχος υποκλυσμός		
		Βαριούχο γεύμα		
		Σιαλπιγγογραφία		
		Κυστεογραφία		
		Μέτρηση οστικής πυκνότητας		

Ε ΤΑΕ 04 ΕΚΔ01/ΑΝΑ802

Αριθμός εξετάσεων σε ΕΡΓΑΣΤΗΡΙΑ ΑΞΟΝΙΚΗΣ ΤΟΜΟΓΡΑΦΙΑΣ

Επωνυμία Εργαστηρίου .....

Έτος :				
	Περιοχή	**Εξέταση**	**Αριθμός εξετάσεων**	**Αριθμός ασθενών**
ΑΞΟΝΙΚΗ ΤΟΜΟΓΡΑΦΙΑ	Κεφάλι	CT εγκεφάλου		
		CT ιγμορείων-κόλπων προσώπου		
		CT ακουστ. πόρων/λιθοειδών		
		CT οστών προσώπου/CT γνάθων (οδοντιατρική)		
		CT αιμάτωσης εγκεφάλου (CT perfusion)		
	Αυχένας	CT τραχήλου		
		CT ΑΜΣΣ		
	Κορμός	CT θώρακος & άνω κοιλίας		
		CT θώρακος & άνω/κάτω κοιλίας		
	Θώρακας	CT θώρακος		
		CT ΘΜΣΣ		
	Κοιλία	CT (πλήρους) κοιλίας		
		CT άνω κοιλίας		
		CT κάτω κοιλίας		
		CT ΟΜΣΣ		
		CT οστών λεκάνης-ισχίων		
		CT (virtual) κολονοσκόπηση		
	Άκρα	CT άνω ή κάτω άκρων		
	Λοιπές			
ΑΞΟΝΙΚΗ ΑΓΓΕΙΟΓΡΑΦΙΑ		CT αγγειογραφία εγκεφάλου		
		CT αγγειογραφία καρωτίδων		
		CT αγγειογραφία πνευμονικών αρτηριών		
		CT στεφανιογραφία		
		CT αγγειογραφία θωρακικής αορτής		
		CT αγγειογραφία κοιλιακής αορτής		
		CT αγγειογραφία ήπατος		
		CT αγγειογραφία νεφρών		
		CT αγγειογραφία άνω ή κάτω άκρων		

Ε ΤΑΕ 04 ΕΚΔ01/ΑΝΑ802

Αριθμός εξετάσεων σε ΕΡΓΑΣΤΗΡΙΑ ΕΠΕΜΒΑΤΙΚΗΣ ΑΚΤΙΝΟΛΟΓΙΑΣ

Επωνυμία Εργαστηρίου .....

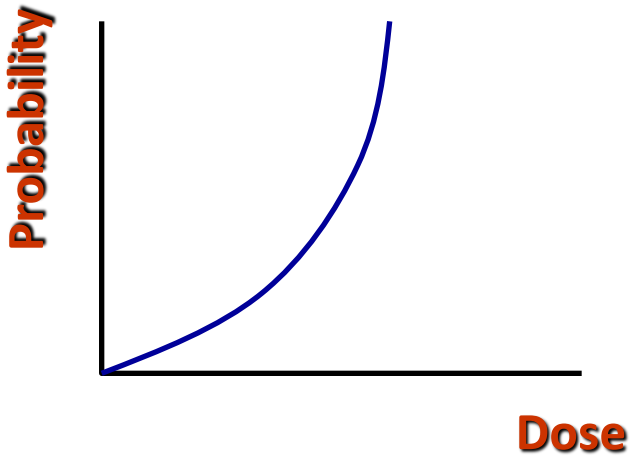
Έτος :				
	Εξέταση	**Αριθμός εξετάσεων**	**Αριθμός Ασθενών**
ΕΠΕΜΒΑΤΙΚΗ ΚΑΡΔΙΟΛΟΓΙΑ	(Απλή) στεφανιογραφία (CA)		
	Στεφανιογραφία/Στεφανιοπλαστική (CA/PTCA/Stenting)		
	Εμφύτευση βηματοδότη		
	Εμφύτευση απινιδωτή		
	RF ablation		
	Παιδιατρικές		
ΛΟΙΠΕΣ ΚΑΡΔΙΟ-ΛΟΓΙΚΕΣ			
ΕΠΕΜΒΑΤΙΚΗ ΑΚΤΙΝΟΛΟΓΙΑ	DSA εγκεφάλου (διαγνωστική)		
	Εμβολισμοί εγκεφάλου		
	DSA καρωτίδων (διαγνωστική)		
	DSA/PTA καρωτίδων		
	Χολαγγειογραφίες/ Παροχετεύσεις χοληφόρων/ Τοποθέτηση Stent (PTC-Percutaneous Transhepatic Cholangiography)		
	TIPS (Transjugular Intrahepatic Portosystemic Shunt)		
	ERCP		
	Χημειοεμβολισμοί ήπατος		
	DSA νεφρικών αρτηριών (διαγνωστική)		
	DSA/PTA νεφρικών αρτηριών		
	Νεφροστομίες		
	DSA κάτω άκρων και κοιλιακής αορτής (διαγνωστική)		
	DSA/PTA κάτω άκρων και κοιλιακής αορτής		
	Stent Graft (σε ανευρύσματα κοιλιακής αορτής)		
	Σπονδυλοπλαστικές		
	Λοιπές ορθοπεδικές		
	Παιδιατρικές		
ΛΟΙΠΕΣ			

Σημείωση
Η συμπλήρωση του πεδίου «Αριθμός ασθενών» είναι προαιρετική

Effective dose, E

E is related to the 'stochastic' effects of radiation (cancer, leukaemia, hereditary)

It is normal to assume that the probability of a stochastic effect for a given organ or tissue is proportional to the organ dose D_T.



Effective dose, E

E is an ***occupational dose quantity*** based on an age profile for radiation workers

One advantage is that the effective dose
- attempts to measure the risk to the patient,
- may be compared to that of any other radiological procedure as well as natural background exposure

HOWEVER

its application for patient exposures poses to limitations

- UNSCEAR and ICRP strongly emphasises that E **should not** be used directly to estimate detriment from medical exposure.
- E may be used for comparative purposes

Effective dose, E

Problems and limitations

- Measurements or calculations make use of a standard phantom and Monte Carlo simulations
- Partial organ or body irradiation
- Different sized patients, ages, sex
- Many factors (kV, field size, position, mAs, etc) affect energy imparted to the patient and therefore E is weakly correlated
- E requires knowledge of organ doses (i.e. not accurate)
- The weighting factors, w_T are assumed to be the same for radiation workers and for the whole population, age and sex.

Collective dose, S

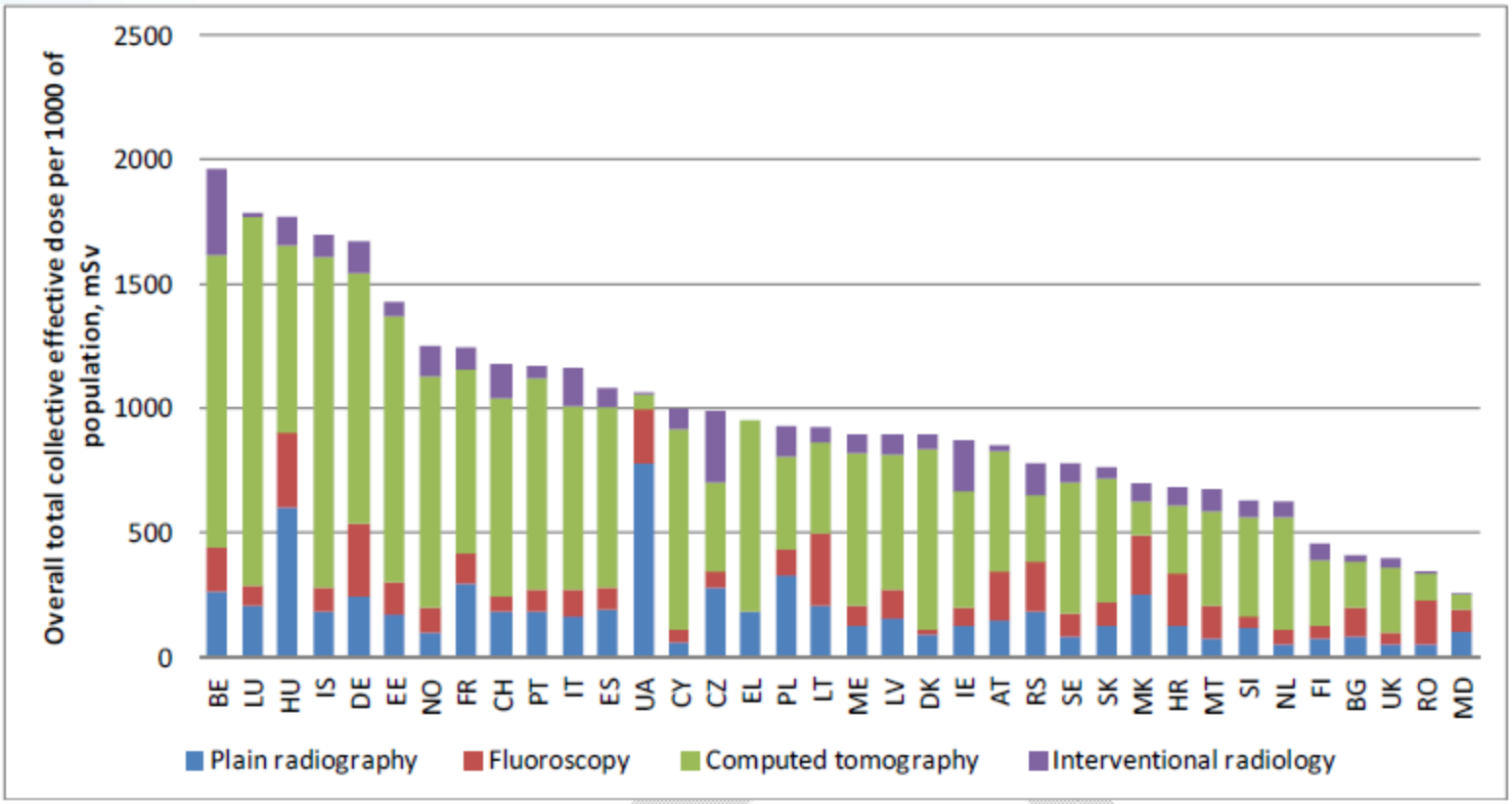
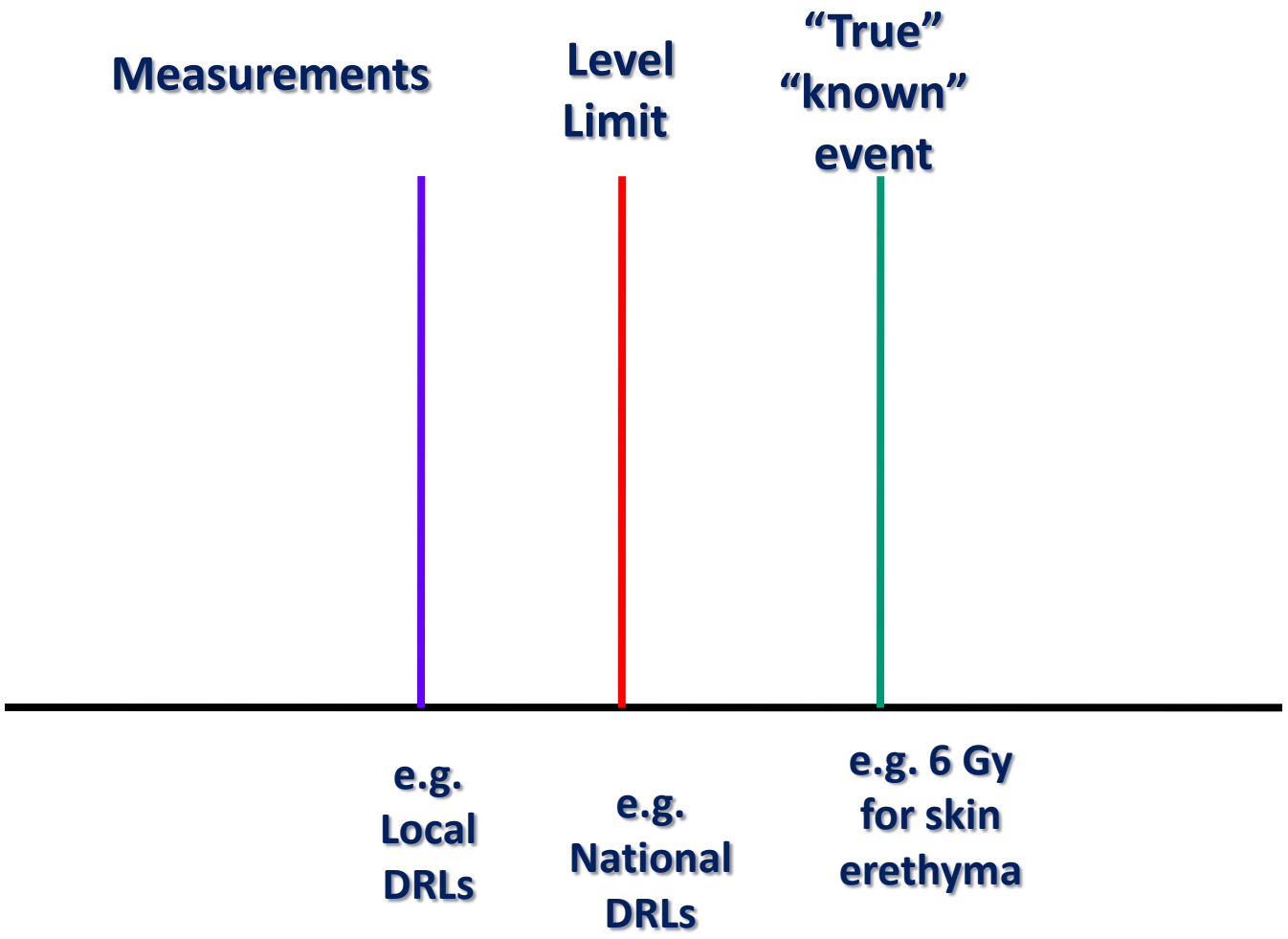


Fig. 5.6. Overall collective effective dose per 1000 population for different countries. The relative contributions of the four main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology) are also shown.

DDM2, report

UNCERTAINTIES



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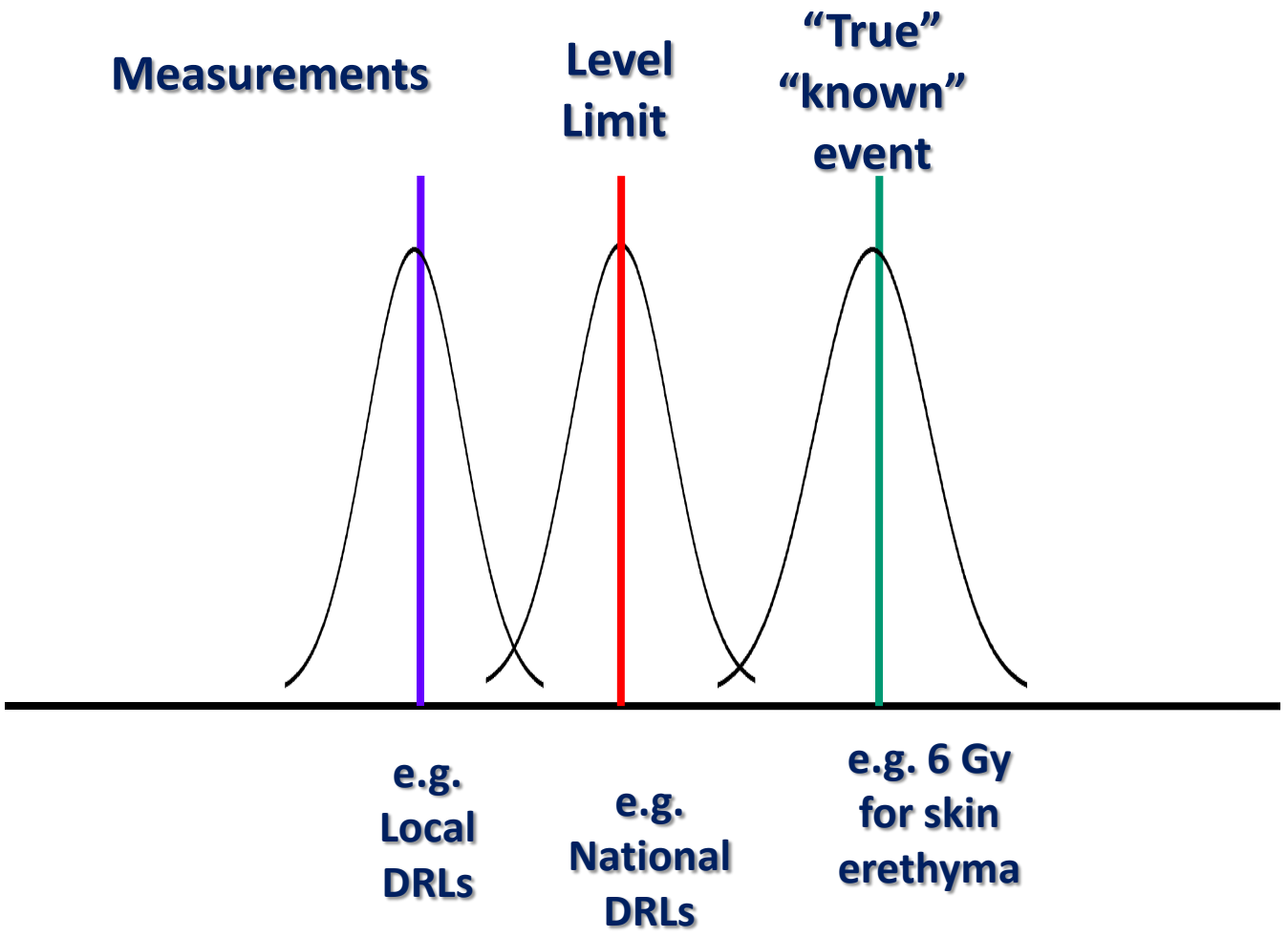

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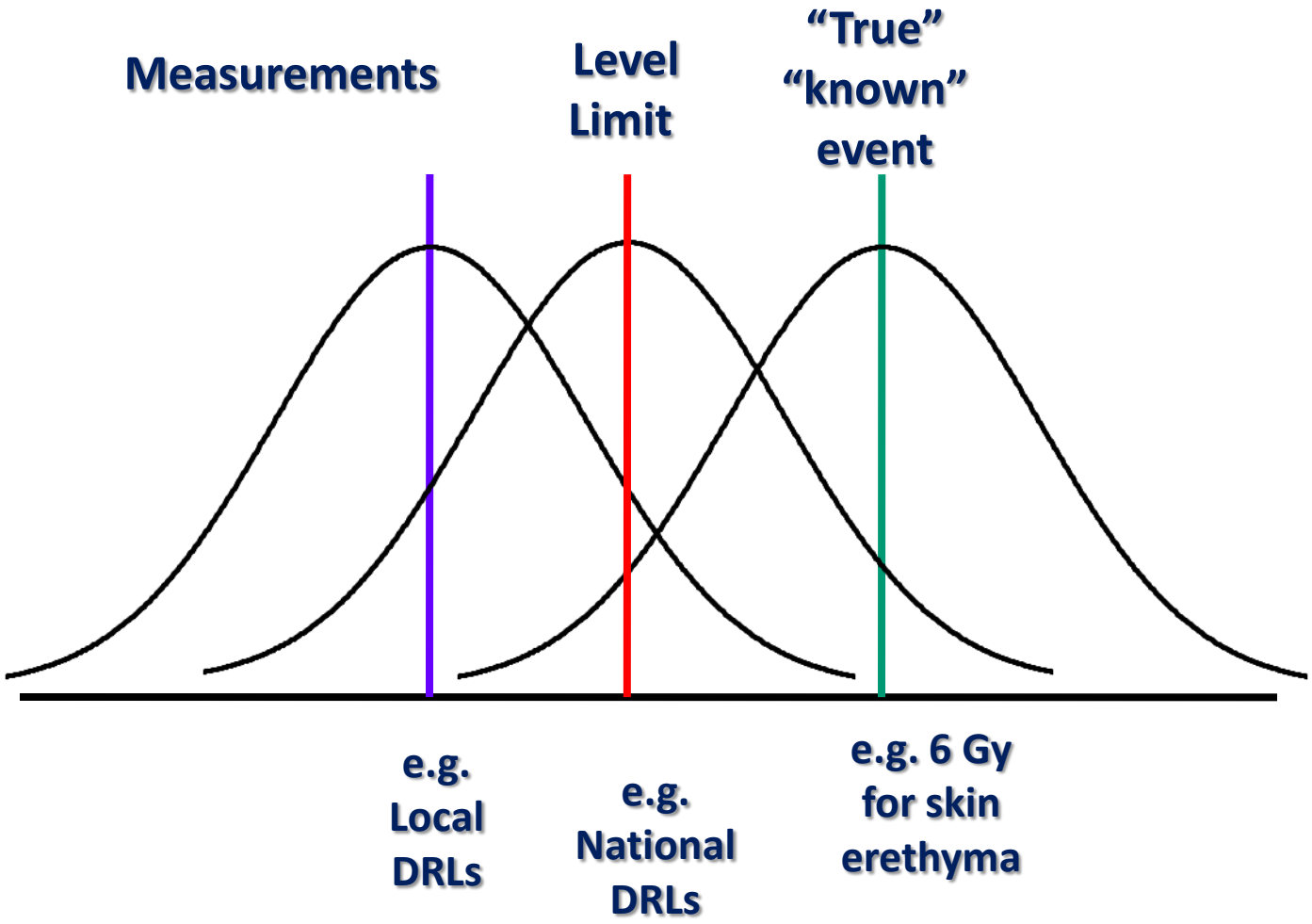

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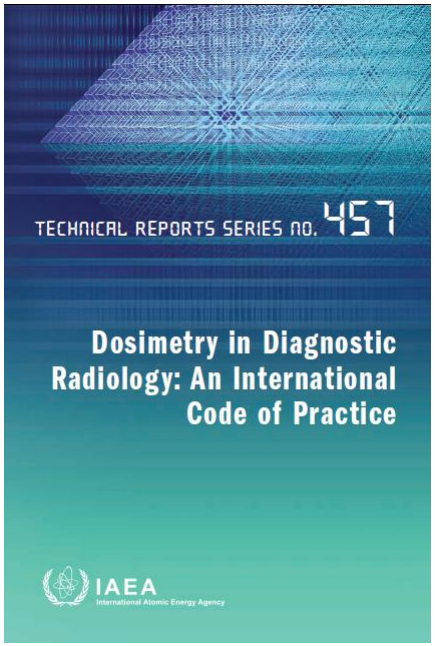

TABLE 8.13. FACTORS CONTRIBUTING TO THE MEASUREMENT UNCERTAINTY IN THE DETERMINATION OF THE CT AIR KERMA INDICES, $C_{a,100}$ AND C_W, USING THE IONIZATION CHAMBER/ELECTROMETER SYSTEM

Source of uncertainty	Uncertainty ($k = 1$)(%)		
	Scenario 1	Scenario 2	Scenario 3
Measurement scenario (see Table 8.2)	6.3	3.5	2.7
Precision of reading	1.0[a]	0.6[b]	0.6[b]
Precision of tube loading indication	1.0	1.0	1.0
Precision of chamber/phantom positioning in the centre of the gantry	0.3	0.3	0.3
Uncertainty of 1 mm in phantom diameter and 0.5 mm in depth of measurement bores[c]	0.35	0.35	0.35
Uncertainty in chamber response for in phantom measurements	3.0	3.0	3.0
Relative combined standard uncertainty (k =1) for $C_{a,100}$	6.5	3.7	3.0
Relative expanded uncertainty ($k = 2$) for $C_{a,100}$	**13.0**	**7.4**	**6.0**
Relative combined standard uncertainty ($k = 1$) for C_W	7.2	4.8	4.2
Relative expanded uncertainty ($k = 2$) for C_W	**14.4**	**9.6**	**8.4**

Conclusion

- Radiation safety and patient dose optimization will always be challenging
- Patient dose should be correlated to image quality
- Advanced dosimetry methods are needed for “new technology” modalities
- DRL is an optimization tool and can serve as a useful performance indicator for patient radiation safety, as well
- High professional skills and effective co-operation between hospital staff, including management, is necessary
- Uncertainties should be taken into account, especially when comparisons are performed.

I thank you for your attention