

Effective dose or dose area product as a measure for reference dose values

Calculation of patient dose values from beam quality, tube current, exposure time, exposed area and focus object distance



Anders Tingberg

Anders Tingberg
Dept. of Radiation Physics
Malmö University Hospital, Sweden



Dept of Radiation Physics, Malmö University Hospital

DAP and reference levels

- Reference level = Maximum dose for a given examination at standard conditions
- Reference level expressed in suitable quantities:
 - Conventional: DAP or ESD
 - Mammography: Average Glandular Dose (AGD)
 - CT: Dose Length Product (DLP) or CTDI_w

Factors influencing patient dose

→ Beam quality

- kV, filtration, anode material, anode angle

→ Dose rate

- mA

→ Exposure time

→ Size of x-ray field and body region irradiated

→ Requirements on image quality

→ Skill of radiologist

What can be done to lower patient dose?

- Smaller x-ray field (collimation)
- Compression
- Match beam quality to sensitivity of detector
- Better detector system
 - More sensitive detector (higher DQE)
 - Better image processing
- Training of staff (especially radiologists)
 - Accept lower image quality
 - Quicker decisions (fewer images, shorter fluoroscopy time)

The DAP concept

- DAP = Dose Area Product
- DAP is a combination of beam quality, mAs and field size

DAP or KAP?

- DAP = Dose Area Product
- KAP = Kerma Area Product
- Kerma = Kinetic Energy Released in Matter by ionising radiation
- For x-ray photon energies:
Kerma \approx Dose
(Range of secondary e^- very short)

DAP meter



DAP meter

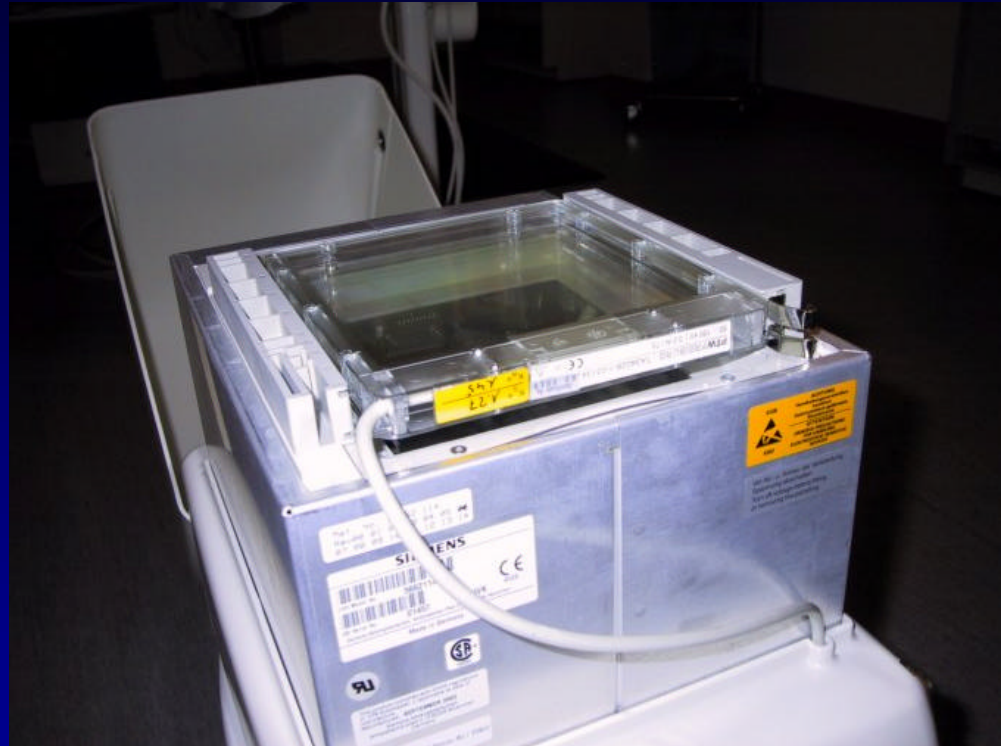
- The DAP meter is a transmission ion chamber
- Collects the charge produced by the x-rays in the chamber
- Produced charge proportional to the dose
- The chamber attenuates ca 10% of the dose

DAP meter mounted on x-ray tube



Other options

→ Built-in DAP meter



→ Calculated DAP value based on field size, beam quality and mAs

ESD

- ESD = Entrance Surface Dose
- The dose at the centre of the x-ray field
- Includes back scatter
- Almost independent of field size
- Usually measured with TLD (sometimes with semi conductor)

TLD

- TLD = Thermo Luminiscent Dosimeter
- Small pellets ($\approx 5 \times 5 \text{ mm}^2$), usually LiF
- Integrating dosimeter
- Light proportional to absorbed dose emitted when heated
- Light counted with PM tube in TLD reader

TLD system



TLD pellets (and tooth pick)

TLD reader



Comparison between DAP and ESD

- DAP takes field size into account, ESD does not
- DAP independent of focus-skin distance, ESD is not
- DAP measured with ion chamber
- ESD measured with TLD

DAP meter compared to TLD

- + DAP values can easily be recorded by radiographers
- + Good educational tool – immediate feedback
- +/- Requires physicist on site
- + Can be used as many times as needed
- + Easy to handle when mounted (TLD material is poisonous, and sensitive to moisture and dust)

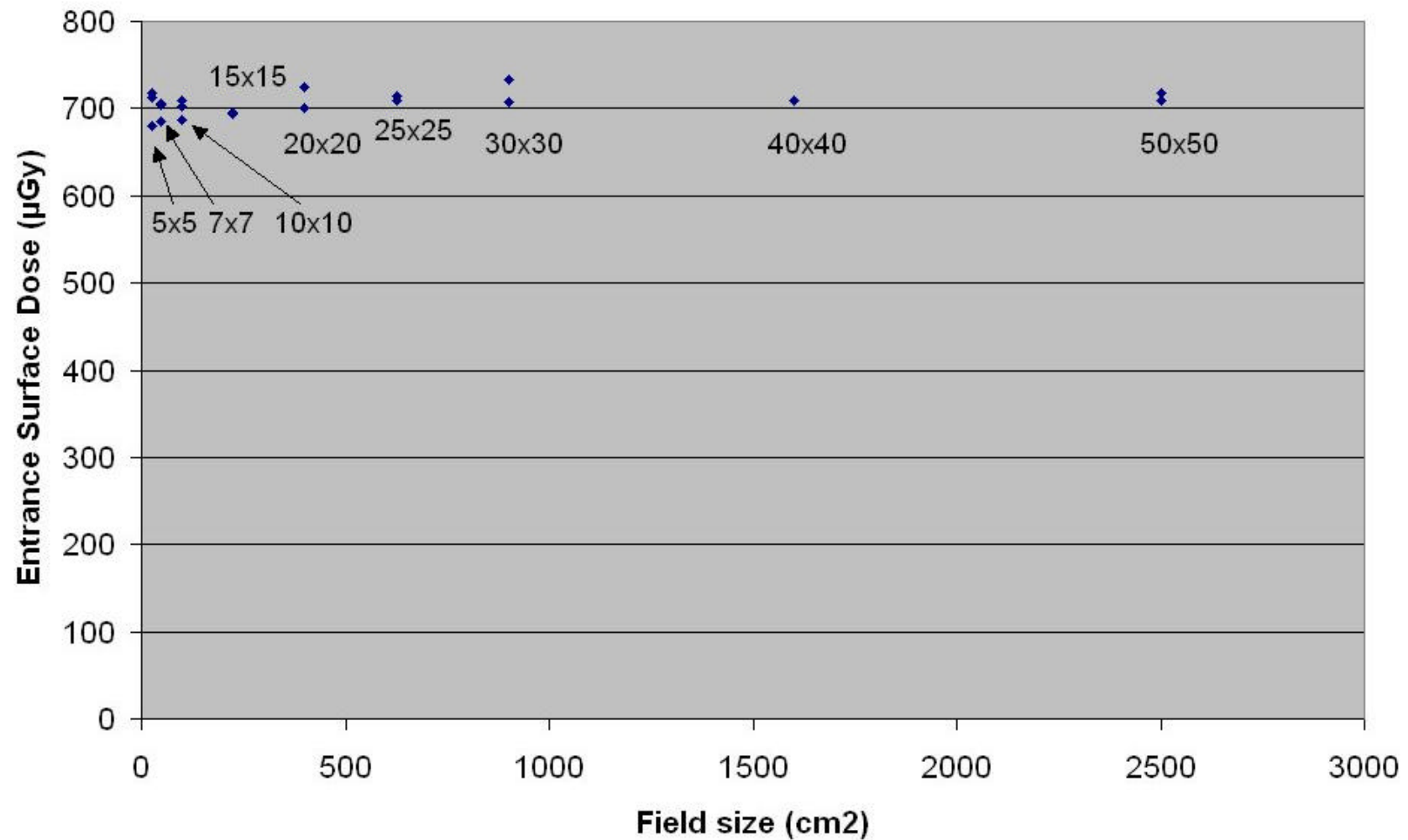
DAP meter compared to TLD

- Two quantities combined (dose and area)
- Calibration procedure more complicated
- Cannot be handled remotely

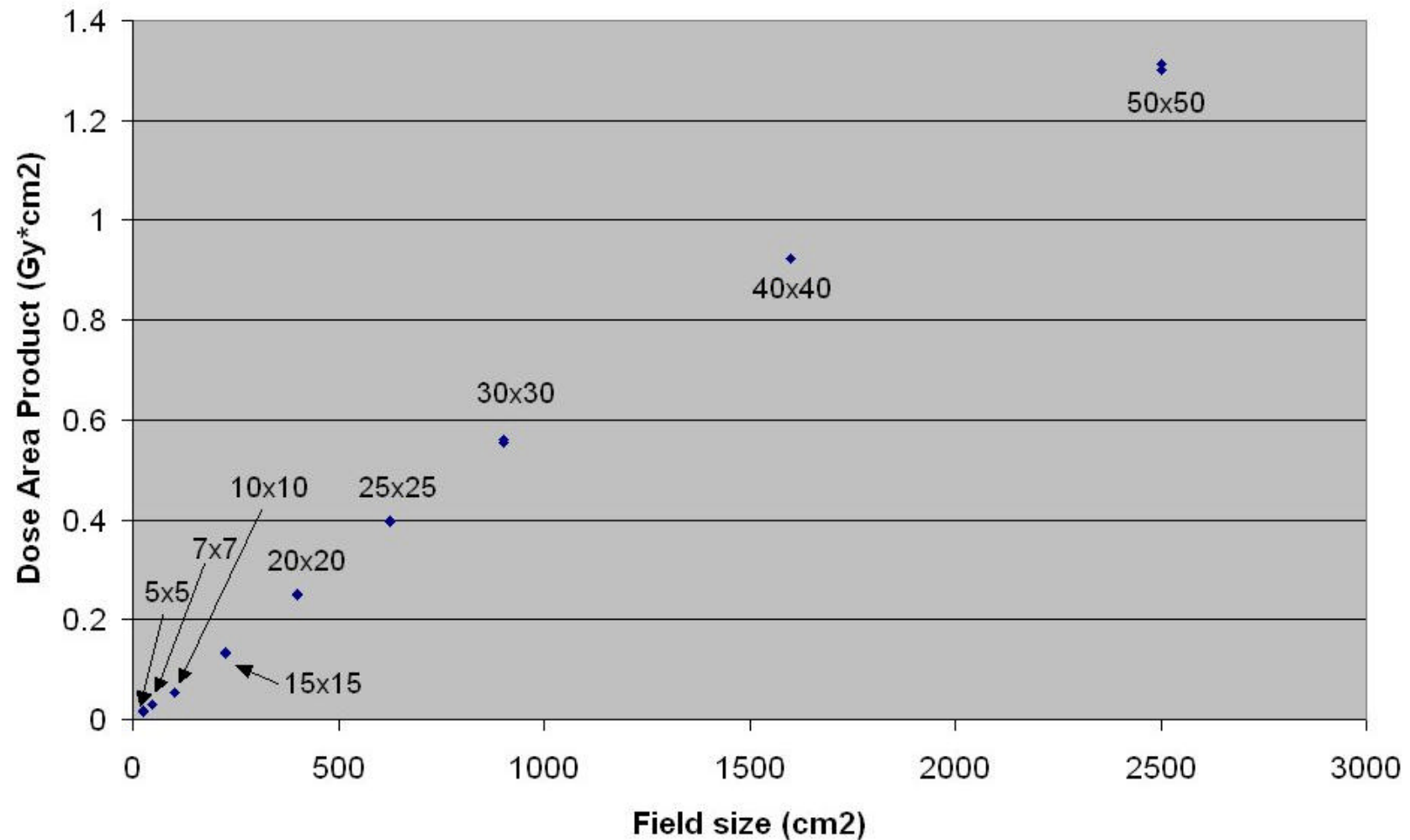
The relevance of DAP with respect to risk

- Effective dose is proportional to field size: the bigger part of the patient that is irradiated the higher the effective dose (constant mAs)
- Best way to reduce effective dose (and increase the image quality!) is to reduce the irradiated volume

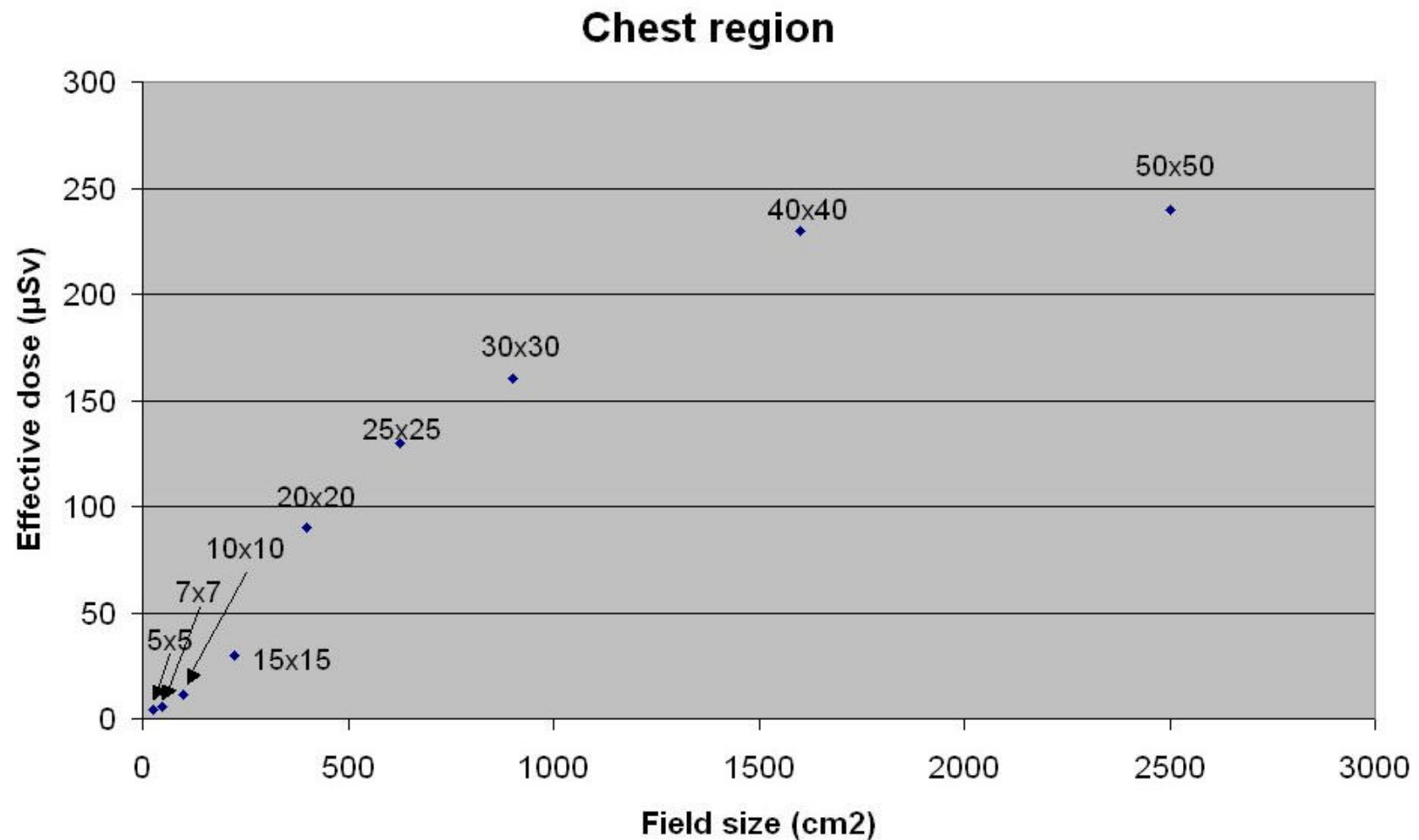
ESD vs. field size



DAP vs. field size



Effective dose vs. field size



Caveats – Lateral chest

- Normal collimation
- DAP = 0.5 Gy cm^2



Caveats – Lateral chest

→ Lax collimation

→ In this case:

$$\text{DAP} = 0.7 \text{ Gy cm}^2$$

No extra risk for
patient!



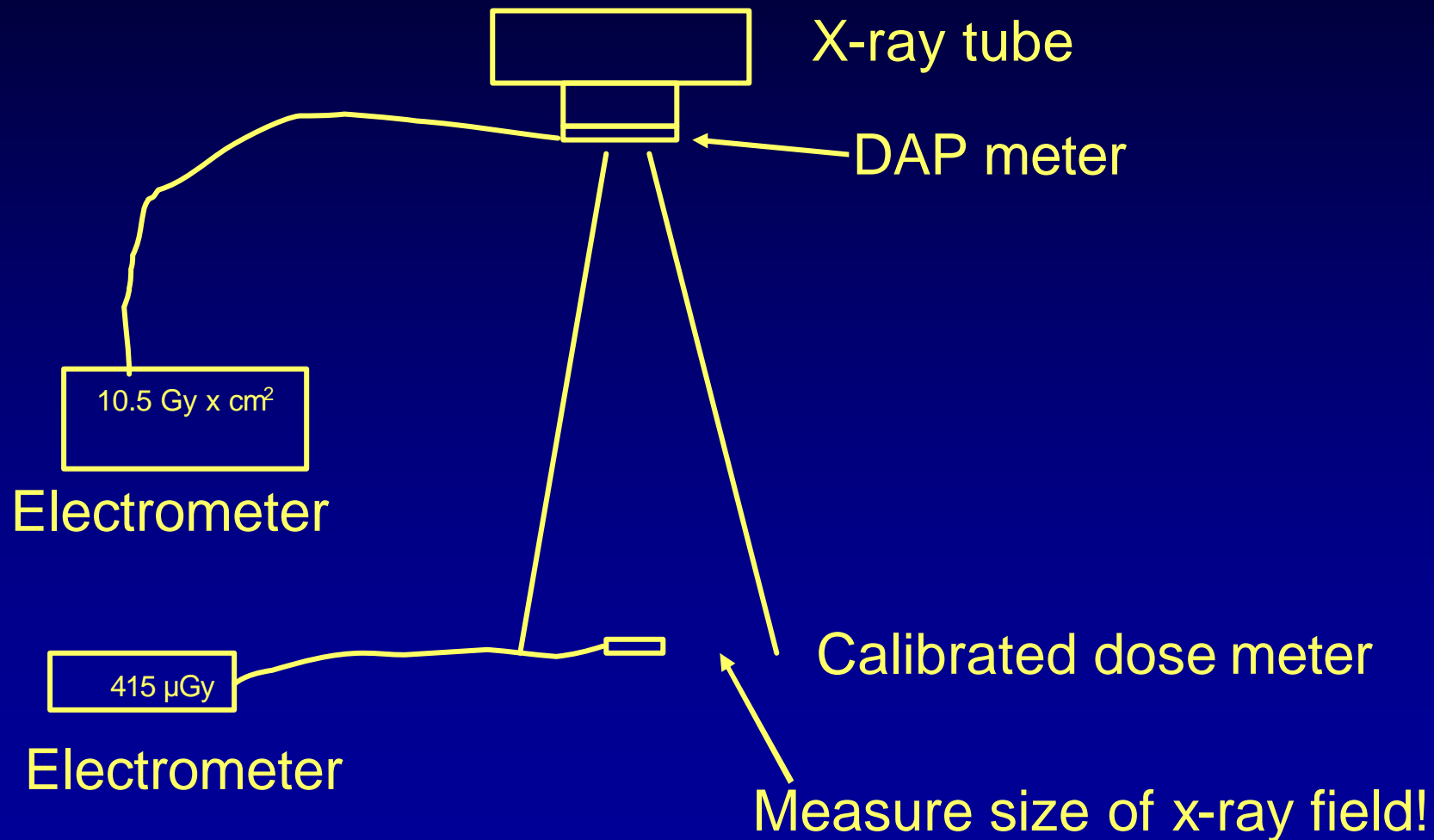
Caveats – Calibration of DAP meter

- Some DAP meters calibrated with respect to the dose impinging to the chamber
- Others with respect to the dose coming out of the chamber (thus hitting the patient)
- The DAP hitting the patient is what we are interested in!

Caveats – Calibration of DAP meter

- Built-in DAP meters may be calibrated at strange beam qualities
- Presented DAP up to 2x the real value
- Obviously very important when measuring diagnostic standard doses

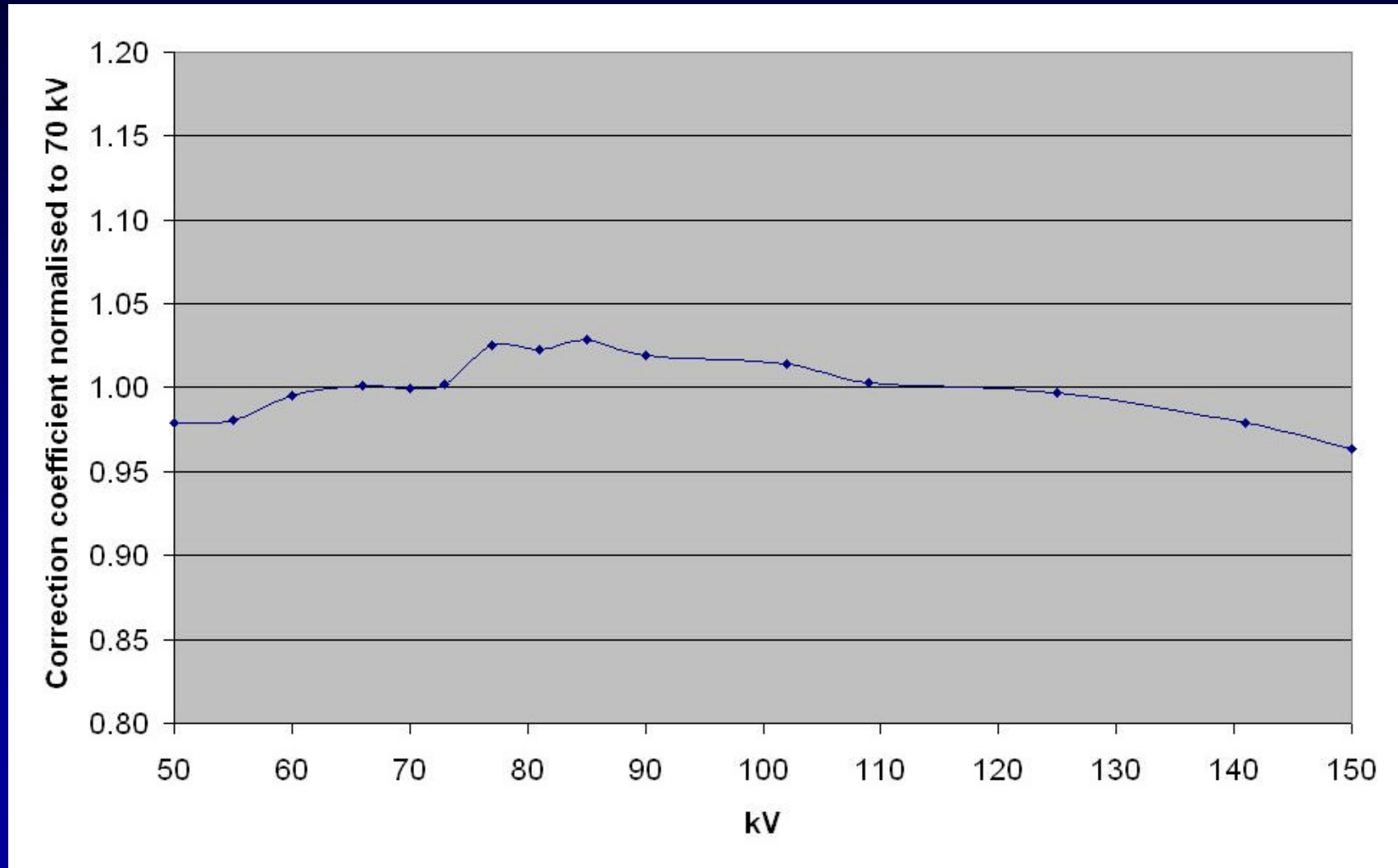
Calibration of DAP meter



Calibration of DAP meter

- Put DAP meter in position at outside window of x-ray tube
- Put calibrated dose meter in x-ray field
 - Calibrated at different beam qualities!
 - E.g. calibrated semiconductor dose meter
- Determine response of DAP meter at different beam qualities

Correction Coefficients



Calculation of effective dose (E)

→ Computer software or table

→ Input values:

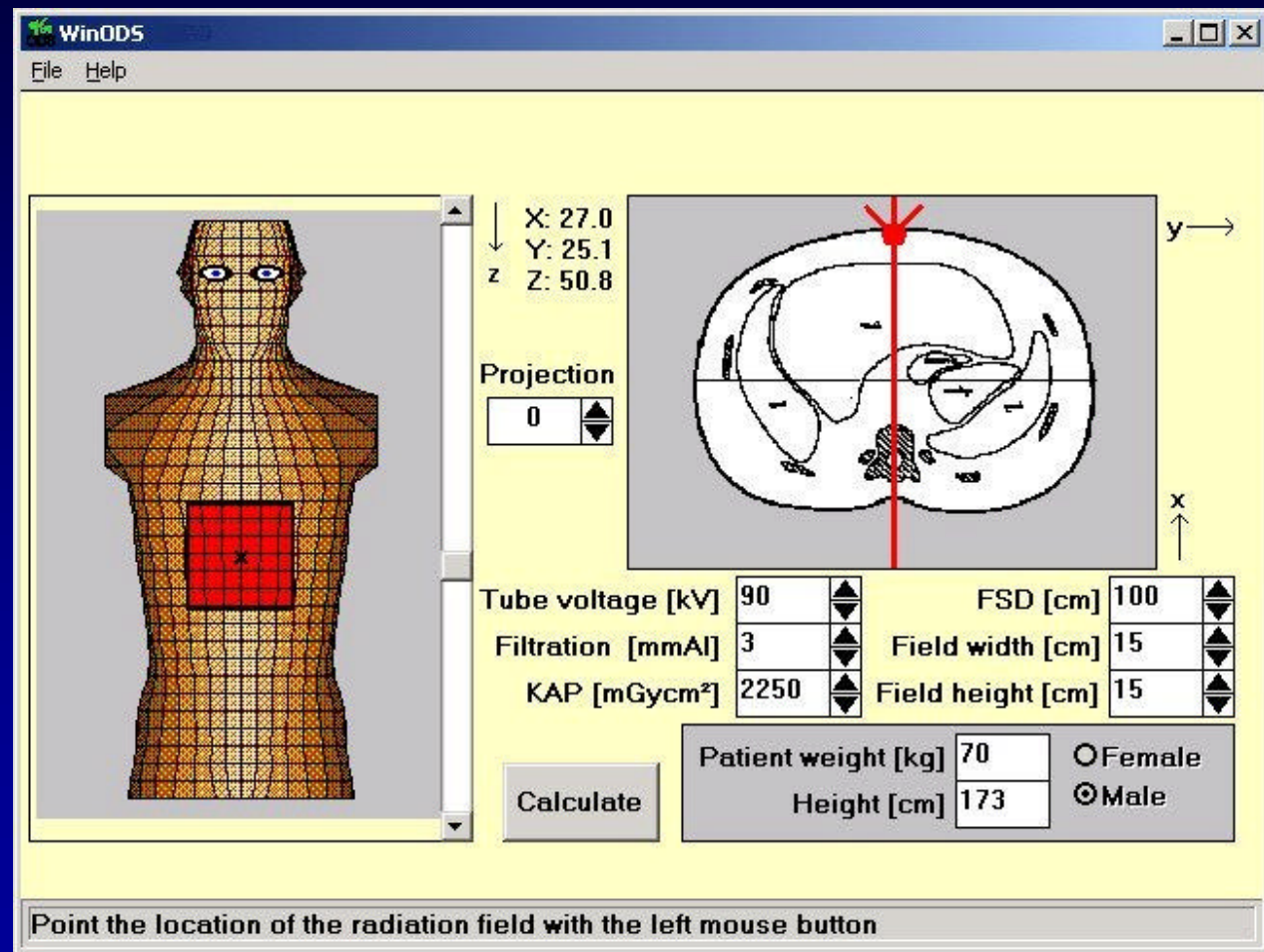
- Exposure parameters: kV, filtration, FSD, field size, DAP or ESD
- Examination info: irradiated body region
- Patient information: height, weight, sex

→ Output values:

- Organ doses and effective dose

Software packages

→ WinODS



Software packages

→ NRPB
tables
(SR 262)
and
EffDose

Estimation of Effective Dose

File Projection... Air Kerma...

Examination description

Chest PA

Potential (kV)

120.0

Filtration (mm Al)

5.00

Dose

☒ Dose Area Product (DAP)

☐ Entrance Surface Dose (ESD)

0.6 Gy×cm²

Selected projection

Chest PA (35×44cm)

Effective Dose

0.14mSv

Examination

	Projection	DAP/ESD	Eff. Dose
1	Chest PA (35×44cm)	0.6 Gy×cm²	0.14mSv

Add

Delete

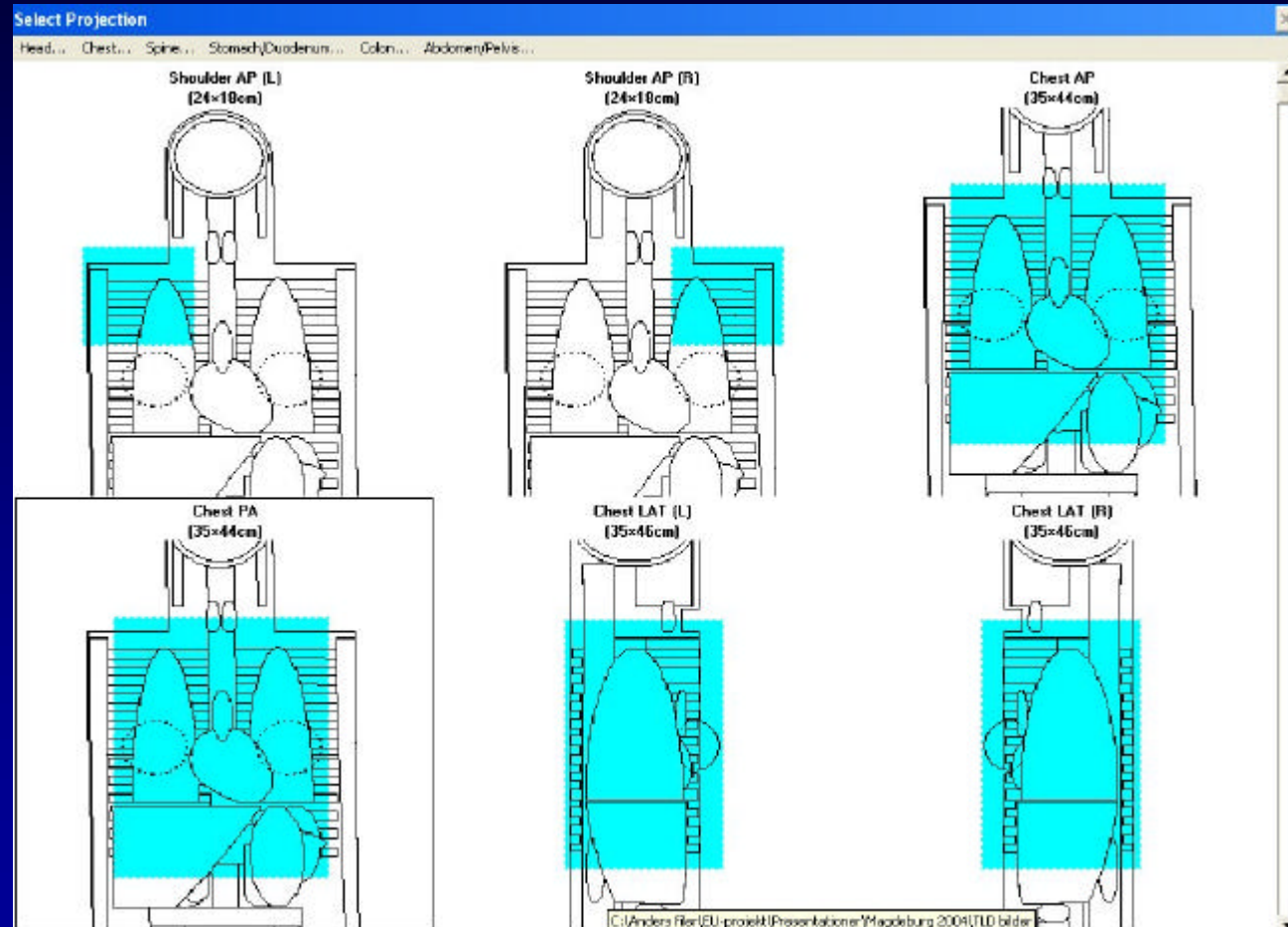
Organ Doses

Summed Effective Dose of the Examination (ICRP 60): 0.14 mSv

Info:

Software packages

→ NRPB
tables
(SR 262)
and
EffDose



Software packages

→ NRPB
tables
(SR 262)
and
EffDose

The screenshot shows a software window titled "Summed Doses" with a blue header bar and a close button in the top right corner. The window is divided into three main sections: "ICRP Organ Doses (mGy)", "ICRP Remainder Organ Doses (mGy)", and "Effective Dose (mSv)".

ICRP Organ Doses (mGy)

Breasts:	0.11
Stomach:	0.13
Lower large intestine:	0.00
Liver:	0.22
Lungs:	0.44
Ovaries:	0.00
Skin (excl. the eye lens):	0.08
Testicles:	0.00
Thyroid:	0.06
Urinary bladder:	0.00
Esophagus:	0.27
Skeleton (bone surfaces):	0.25
Red bone marrow:	0.15

ICRP Remainder Organ Doses (mGy)

Adrenals:	0.51
Brain:	0.00
Small intestine:	0.01
Upper large intestine:	0.02
Kidneys:	0.31
Pancreas:	0.25
Spleen:	0.42
Thymus:	0.10
Uterus:	0.00
Residual tissues(muscle):	0.09

Effective Dose (mSv)

Effective dose:	0.14
Effective dose equivalent:	0.20

Other Organ Doses (mGy)

Eye lens:	0.00
Gall bladder:	0.10
Heart:	0.20
Head region:	0.04
Trunk region:	0.20
Leg region:	0.00

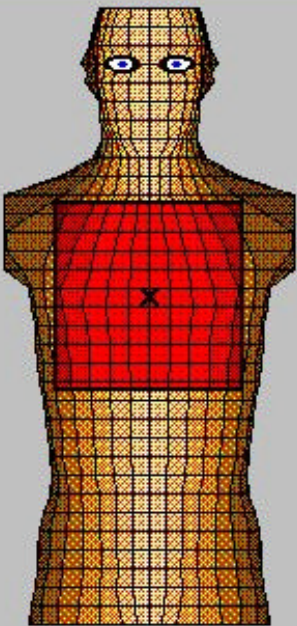
At the bottom of the window is an "OK" button.

Example of E calculation

WinODS Database: \ODS.MDB

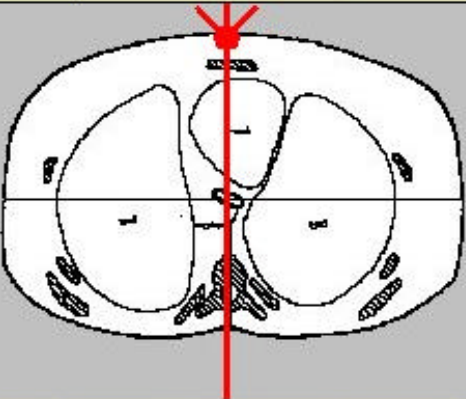
File Options Doseguard Help

database	patient	examination
	radiologist	end



X: 27.5
Y: 25.0
Z: 41.4

Projection
000



y →

x ↑

Tube voltage [kV]	60	FSD [cm]	100
Filtration [mmAl]	5	Field width [cm]	25
KAP [mGycm ²]	609	Field height [cm]	25

Calculate

Patient weight [kg]	70	<input type="radio"/> Female
Height [cm]	173	<input checked="" type="radio"/> Male

Press 'Calculate' button to calculate doses without saving them in the database

Example of E calculation

WinODS Database: \ODS.MDB

File Edit

database		patient	examination
		radiologist	end
Patient length [cm]:	173	ICRP-60 organs [mGy]:	
Patient weight [kg]:	70	Gonads	*
Patient sex:	Male	Bone marrow	0.08
		Colon	*
		Lungs	0.36
Projection [degrees]:	0	Stomach	0.13
Field width [cm]:	25	Bladder	*
Field height [cm]:	25	Breast	-
Field X:	27.5	Liver	0.2
Field Y:	25.0	Oesophagus	0.14
Field Z:	41.4	Thyroid	0.04
FSD [cm]:	100	Skin	0.03
Tube voltage [kV]:	60	Bone surface	0.05
Filtration [mmAl]:	5	Adrenals	0.09
K _a [mGy]:	0.592	Brain	*
		Upper large intest.	0.01
		Small intestine	0.01
		Kidney	0.02
		Muscle	0.03
		Pancreas	0.04
		Spleen	0.12
		Thymus	0.64
		Uterus	-
		Effective Dose	0.11
		[mSv]	

Additional organs

☒ Copy with labels

Copy Print OK

Disable 'Copy with labels' box if labels are not to be copied.

Diagnostic reference level, DRL

- Dose level determined by government for a given examination
- If DRL is exceeded, actions should be taken to lower the dose

DRL, cont'd

- Mean value for a number of patients
- Does not apply to an individual patient!
- Value of DRL is set arbitrarily – often the the 75% level of the distribution within a country is selected

Diagnostic standard dose, DSD

→ Dose level determined at the radiology department for a given examination, measured in the same way as for the DRL

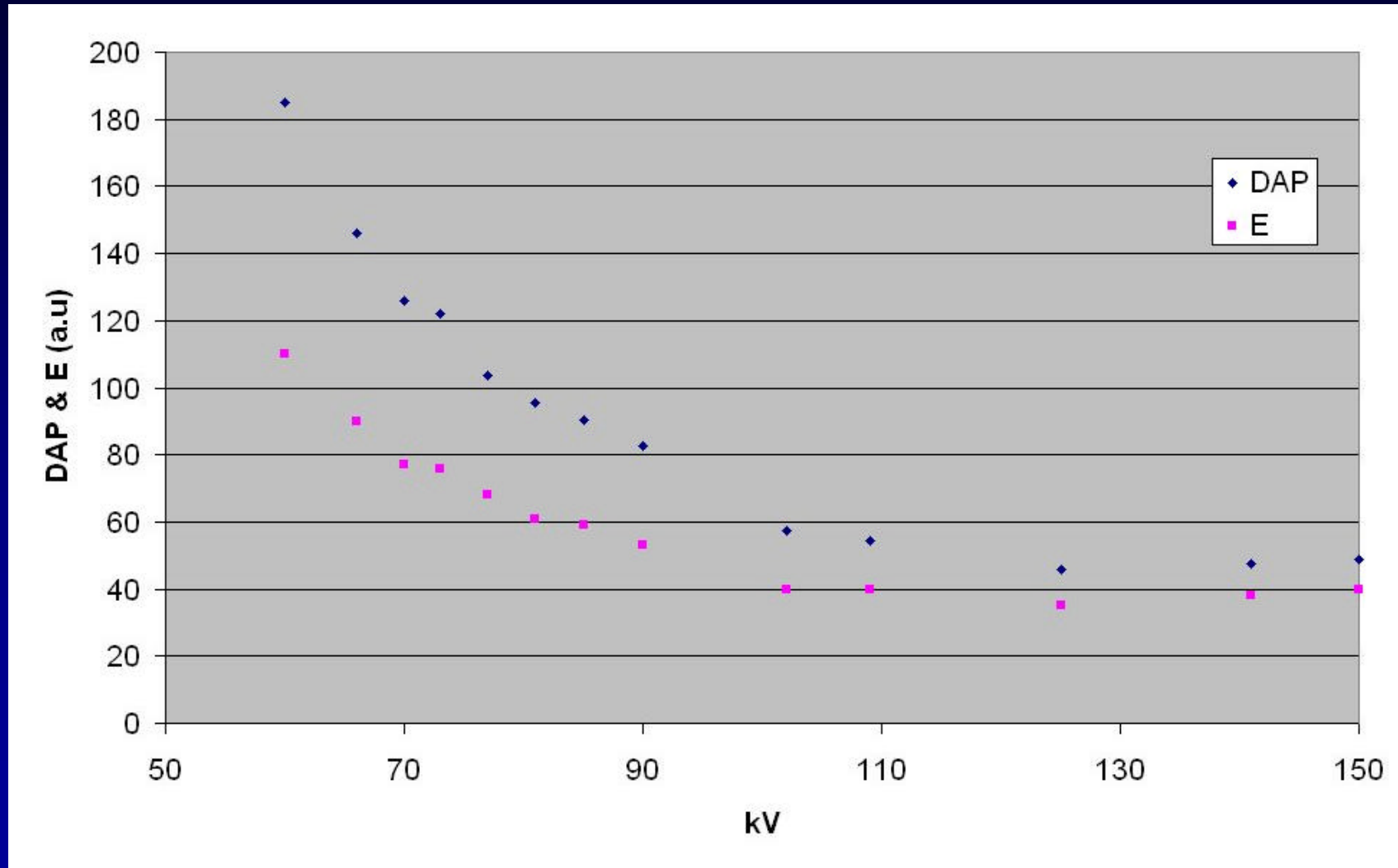
Purpose of DRL

- Identify bad procedures
- Comparisons
- National (and international) dose surveys
- Encourage radiation protection and dose consciousness

How to measure DSD, for a given examination

- Mount DAP meter at x-ray tube
- Provide technicians with measurement protocols (preferably digital)
- Instruct technicians and radiologists carefully
 - Put someone in charge of the measurements
- Be patient...
- Repeat procedure for each x-ray stand

DAP & E vs. kV (AEC)



DAP vs. E

→ E is not linear to DAP

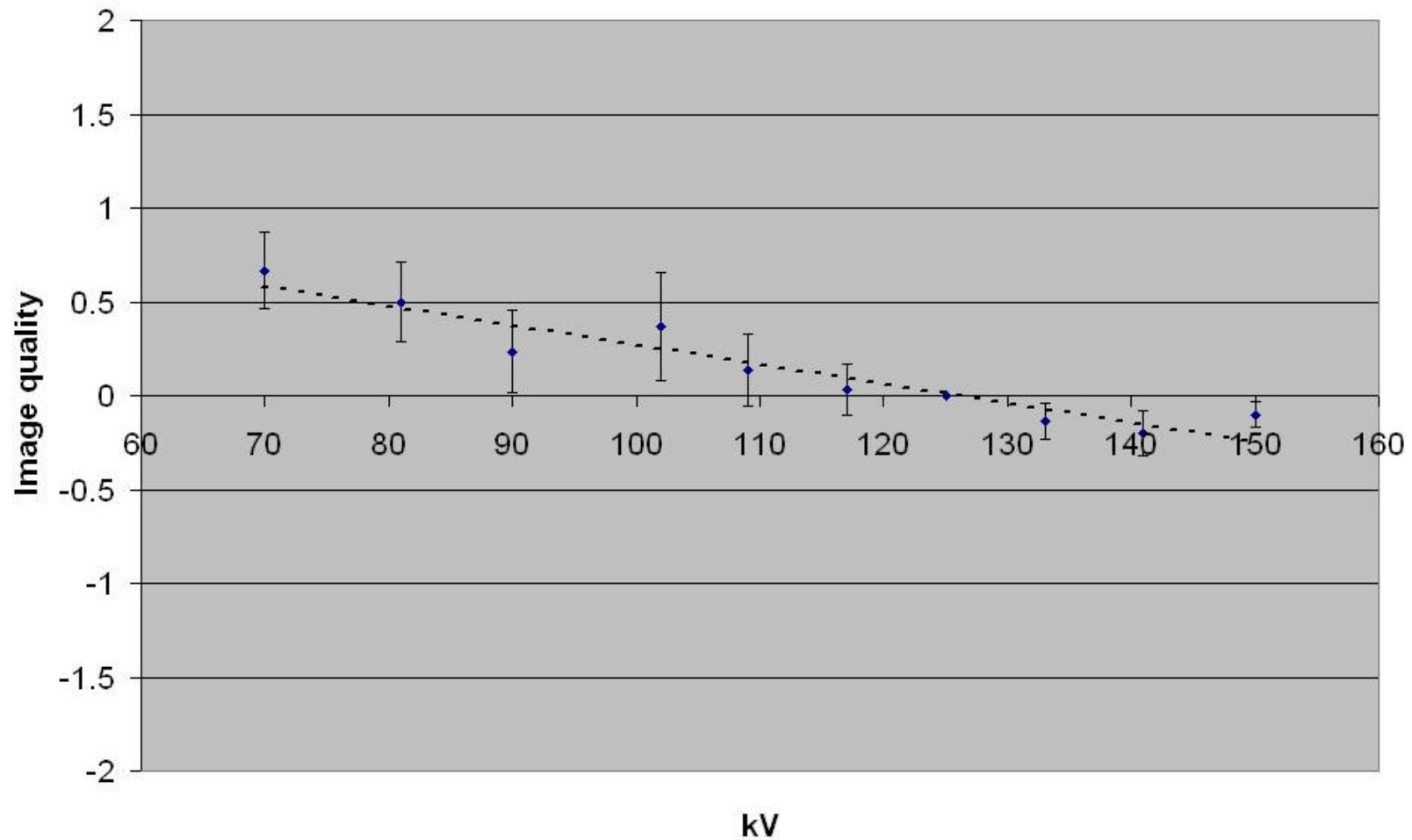
→ Another example:

- Chest PA normal field size vs. small field size
- Same beam quality and DAP
- Normal field: 0.23 μSv
- Small field: 0.27 μSv

Digital detector (Fuji CR)

- Vary kV
- Adjust mAs so that E is constant
- Have radiologists evaluate images
- What happens to image quality?

Chest radiography



DAP or E as the measure for reference level?

- DAP is easy to measure
- But E is not linear to DAP
- Only if beam quality, field size etc. is the same, then E is linear to DAP
- However, E has to be calculated (cannot be measured)

DAP or E as the measure for reference level?

- E depends on beam quality, field size, irradiated body region and DAP
- E is *the* important quantity with respect to risk
- E should (according to my point of view) be the quantity to use for the reference levels

Diagnostic reference levels for image quality

- DRL for patient dose huge step forward for optimising dose in hospitals
- But optimisation work also needs to deal with image quality
- Desirable to find DRL for image quality!

Summary

- DAP more useful quantity than ESD
- E more appropriate than DAP
- DRL very useful tool for medical physicists!

Contact information

E-mail:

anders.tingberg@rfa.mas.lu.se

Go Sweden!



Sweden – Bulgaria 5-0