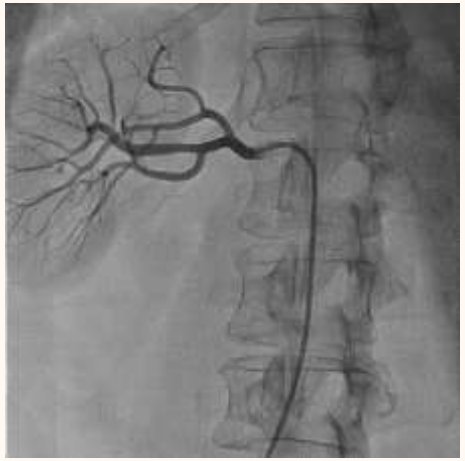
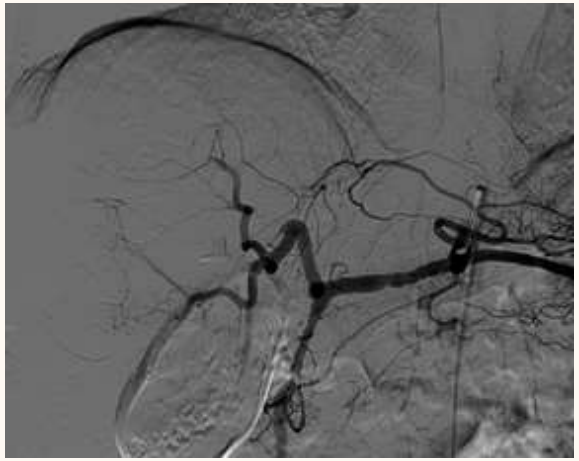
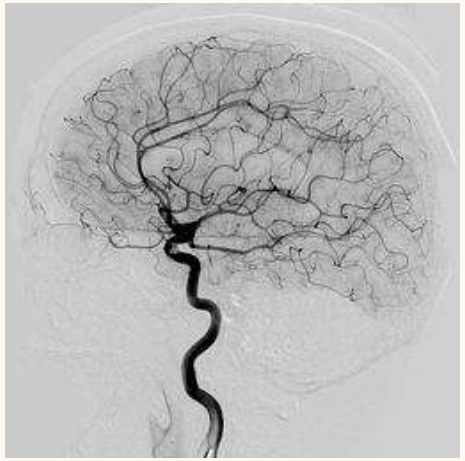
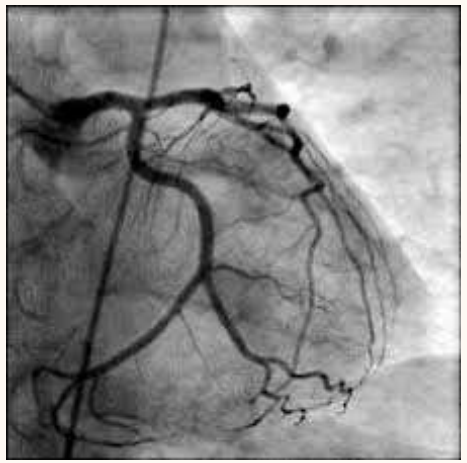

Radiation protection in the cath lab and interventional radiology: practical hints and tricks

PROF. HILDE BOSMANS

MEDICAL PHYSICS EXPERT IN RADIOLOGY

KU LEUVEN

Acknowledgement

My colleagues: Prof. Nick Marshall, Michiel Dehairs, the Leuven medical physics team in radiology

& the medical teams in interventional radiology & cardiology

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The IAEA, and their encouragements to lecture in this webinar. Thank you, Jenia Vassileva.

Conflict of interest

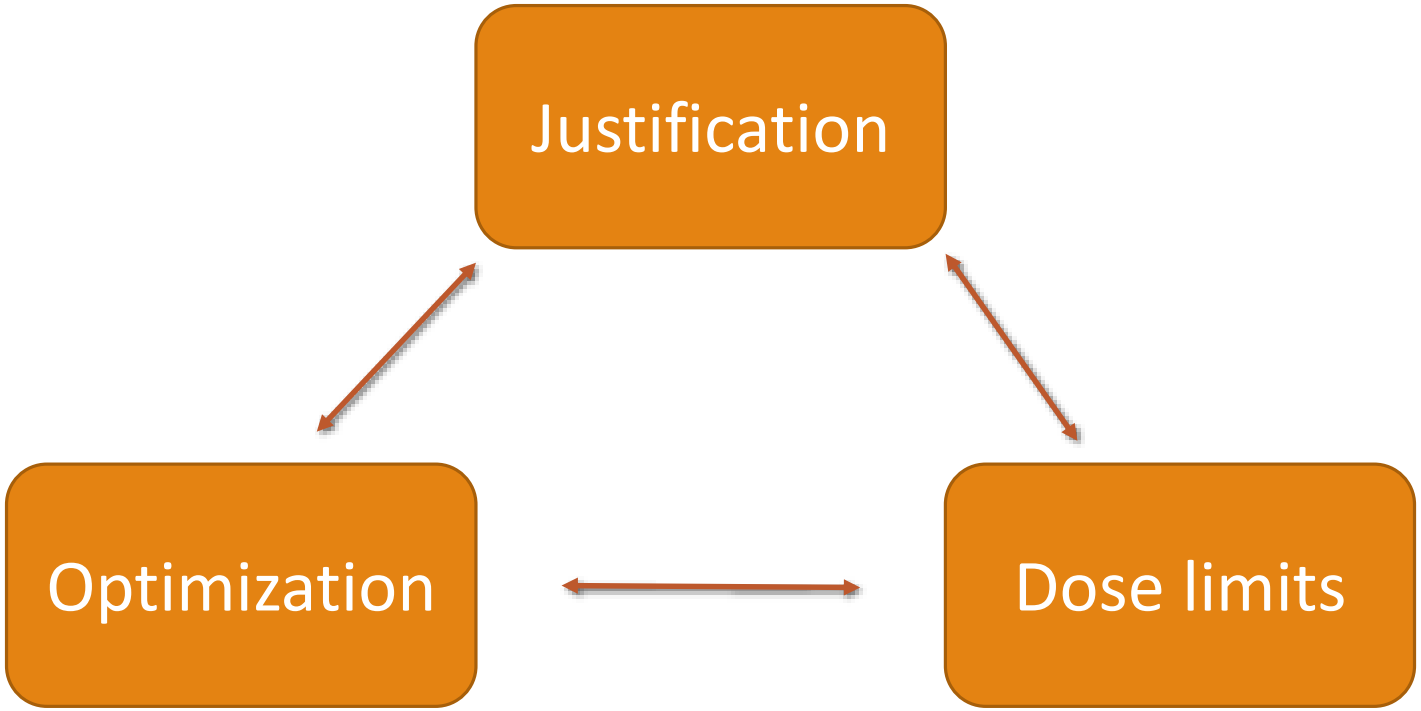
Hilde Bosmans is co-founder and board member of QAELUM NV.

This company provides software packages for dose and quality monitoring, including skin dose mapping

Overview

- The basics: justification, optimization & dose limits
- Get motivated for the lecture
- Radiation protection: time, distance, shielding
- Practical hints and tricks
- A case study: a new combined angio – MR system and impact on radiation protection?

Basic principles of radiation protection



Assure the right test is done on the right patient for the right reason

Justification

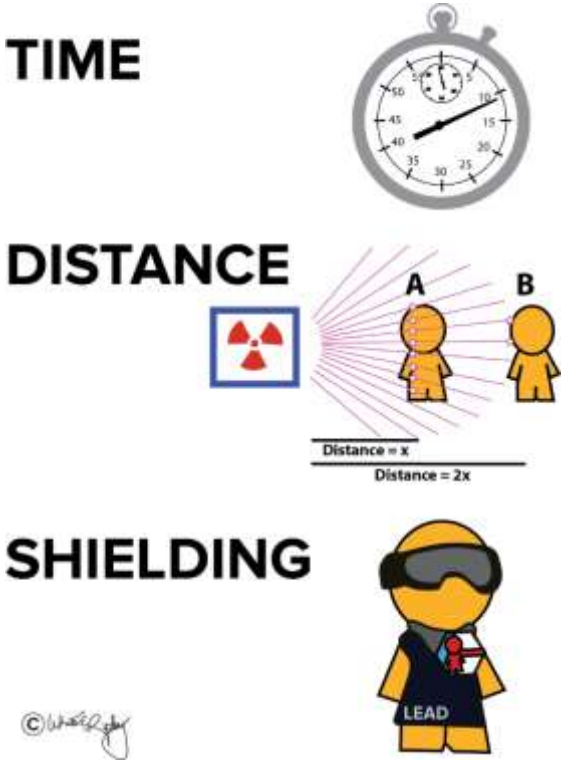
The patient shouldn't receive dose without a potential benefit

Patient outcome

Dose to patient and personnel

Optimization

The medical team is responsible to ensure
the radiological procedure provides quality images,
adequate for diagnosis and treatment,
while keeping the radiation dose
As Low As Reasonably Achievable (ALARA)



Dose limits

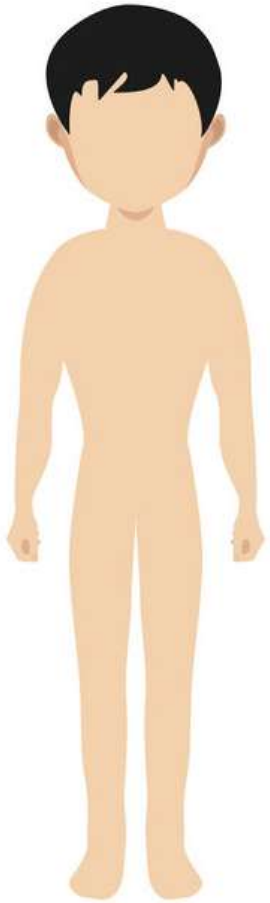
Personnel

Eye lens
20 mSv/year

Whole Body
20 mSv/year

Skin of the whole body
500 mSv/year

Extremities
500 mSv/year

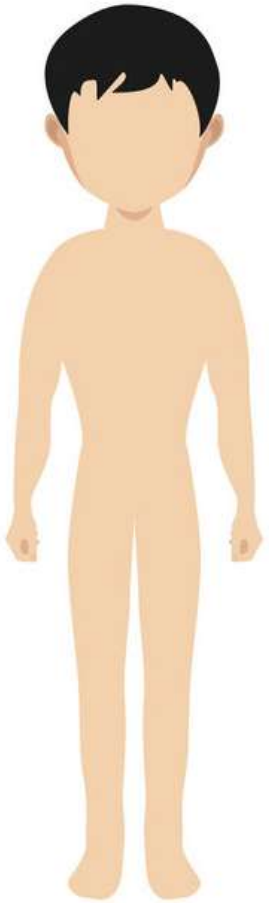


Public

Eye lens
15 mSv/year

Whole Body
1 mSv/year

Skin of the whole body
50 mSv/year

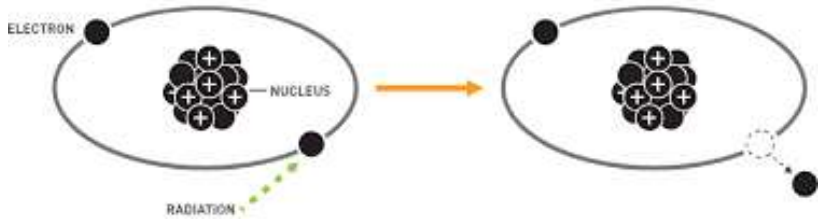


Patients

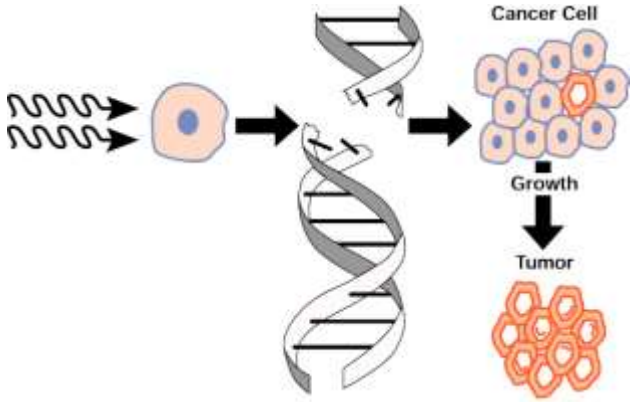
NO LIMITS !

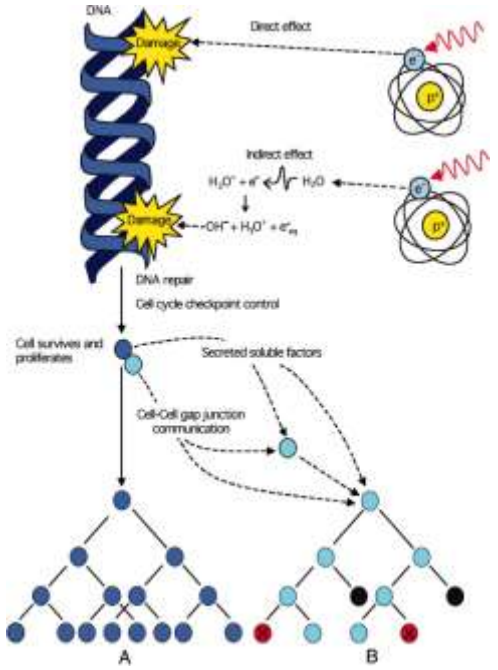
*Look at **DRLs** and trigger levels (More on this later)*

Ionizing radiation



Ionizing radiation is radiation that carries enough energy to remove an electron from an atom or molecule





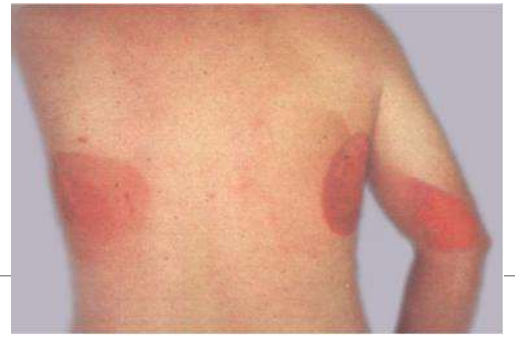
Exposure to ionizing radiation causes damage to living tissue and can results in cell damage and potentially cancer and death

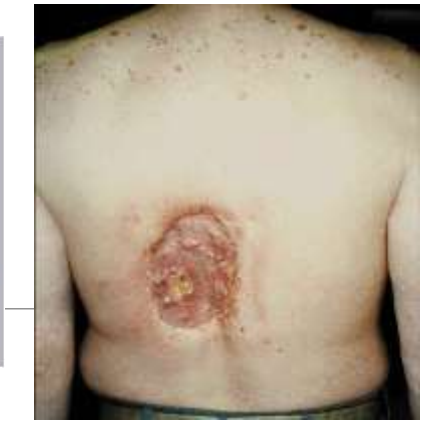
Radiation risks

- Two types
  - The **stochastic** effect is the non-threshold biologic effect of radiation that occurs by chance to a population of persons whose probability is proportional to the dose and whose severity is independent of the dose. For example: cancer development, genetic effects
  - The **deterministic** effect is a dose-dependent direct health effect of radiation with dose threshold. For example: Skin necrosis

- This does not only apply to patients but also to the medical team

Radiation risks (Patients)





- Skin burn is a well-documented radiation induced effect in the Cath Lab

- But there are several other important deterministic effects than can occur:
  - Lens opacities and cataract
  - Affected fertility
  - Reduced count in White Blood Cells

Table A.3.1. Estimates of the thresholds for tissue effects in the adult human testes, ovaries, lens, and bone marrow (from ICRP 1984, *Publication 41*[1]).

Tissue and effect	Threshold		
	Total dose received in a single brief exposure (Gy)	Total dose received in highly fractionated or protracted exposures (Gy)	Annual dose rate if received yearly in highly fractionated or protracted exposures for many years (Gy y^{-1})
Testes			
Temporary sterility	0.15	NA[2]	0.4
Permanent sterility	3.5–6.0[3]	NA	2.0
Ovaries			
Sterility	2.5–6.0	6.0	>0.2
Lens			
Detectable opacities	0.5–2.0[4]	5	>0.1
Visual impairment (Cataract)[5]	5.0[5]	>8	>0.15
Bone marrow			
Depression of hematopoiesis	0.5	NA	>0.4

See Table A.3.4 and Section A.3.1.7 for revised judgements.

[1] For further details consult *Publication 41* (ICRP 1984).

[2] NA denotes Not Applicable, since the threshold is dependent on dose rate rather than on total dose.

[3] See UNSCEAR (1988).

[4] See also Otake and Schull (1990).

Radiation risks (Patients)

No picture

- Increased risk of cancer
- Risk scales with the effective dose,

Table A.4.4. Detriment adjusted nominal risk coefficients for cancer and heritable effects (10^{-2} Sv^{-1})[1].

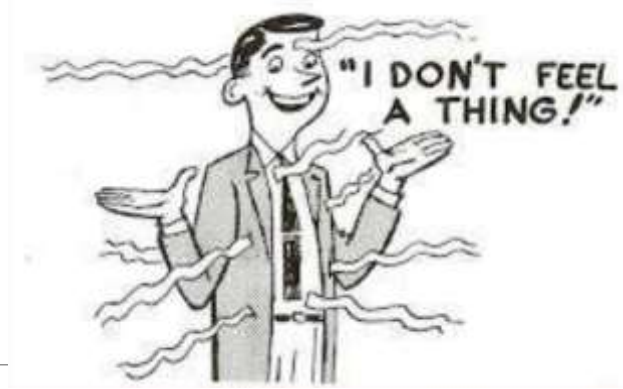
Exposed population	Cancer		Heritable effects		Total	
	Present	ICRP 60	Present	ICRP 60	Present	ICRP 60
Whole	5.5	6.0	0.2	1.3	5.7	7.3
Adult	4.1	4.8	0.1	0.8	4.2	5.6

[1] Values from Tables A.4.1a, A.4.1b, and *Publication 60*.

Typical Patient effective doses for common interventional cardiac procedures

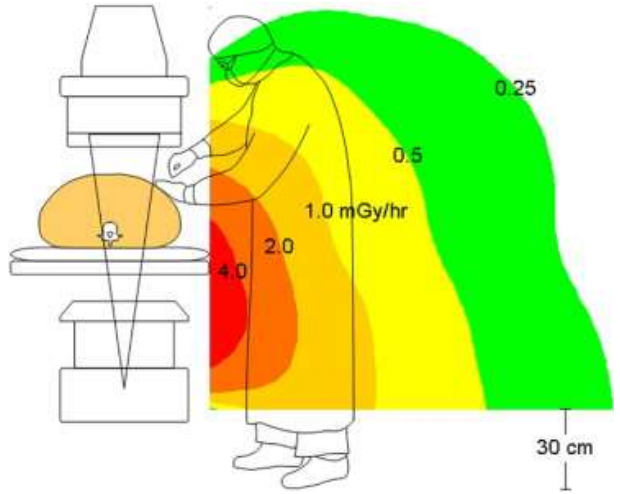
Procedure	mSv*
Diagnostic angiography	7.6 ± 6.0
Diagnostic angiography + percutaneous coronary intervention (PCI)	22.4 ± 16.5
PCI for chronic total occlusion	39.3 ± 30.1
Transcatheter aortic valve replacement (TAVR)	25.6 ± 6.2
*1 mSv = approximately 10 chest X-rays.	

Brilakis ES, Banerjee S, Karmpaliotis D, et al. Procedural outcomes of chronic total occlusion percutaneous coronary intervention: a report from the NCDR (National Cardiovascular Data Registry). *JACC Cardiovasc Interv* 2015;8:245-53.
Andreou K, Pantos I, Tzanalaridou E, Efstathopoulos E, Katritsis D. Patient radiation exposure and influencing factors at interventional cardiology procedures. *Phys Med*2016;32(Suppl 3):234.
García-García HM, van Mieghem CA, Gonzalo N, et al. Computed tomography in total coronary occlusions (CTTO registry): radiation exposure and predictors of successful percutaneous intervention. *EuroIntervention* 2009;4:607-16.



Radiation risks (medical team)

- Interventional Cardiologists experience the highest amount of radiation exposure of any medical professional
  - An increase in the potential complexity of the interventional procedures has again increased the concern to reduce the radiation dose to the personnel
  - Procedures like chronic total occlusions (CTO's), peripheral artery disease (PAD), left atrial appendage occlusion (LAA) and trans catheter aortic valve replacement (TAVR) are much longer and complicated than the common percutaneous coronary interventions (PCI's)



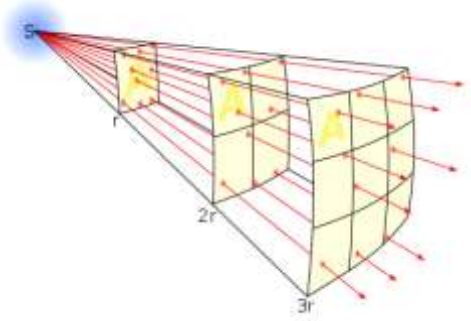
- 'Concerns regarding (left-sided) brain cancer developing in physicians performing interventional procedures' (Am J Cardiol. 2013 May)
- 'A high prevalence of lens changes likely induced by radiation exposure…' (J Vasc Interv Radiol. 2013 Feb;24(2):197-204)
- Thyroid disease and neuro degenerative disease ?

Dose Quantities (‘vocabulary’)

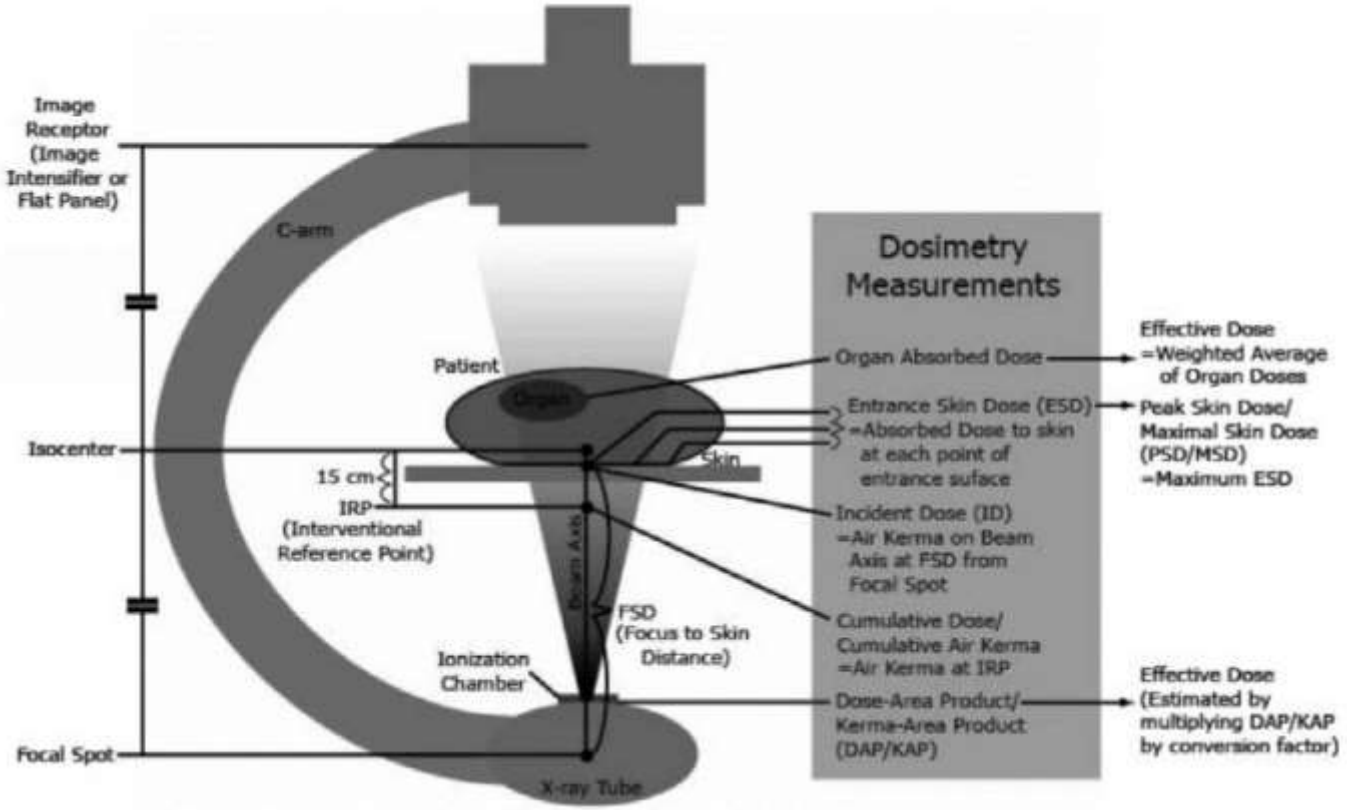
1. Fluoroscopic Time (min) = the time during a procedure that fluoroscopy is used but does not include (cine) acquisition imaging. Therefore, on itself, it tends to underestimate the total radiation dose received.

2. Cumulative Air Kerma (Gy) = a measure of X-ray energy delivered to air at the interventional reference point (15 cm from the isocenter in the direction of the focal spot). This measurement has been closely associated with ***deterministic skin effects***.
(not a true peak skin dose)

3. Dose-Area Product (Gy.cm2) = the cumulative product of the air kerma and the X-ray field area. This monitors the patient dose burden and is a good indicator of ***stochastic effects***.

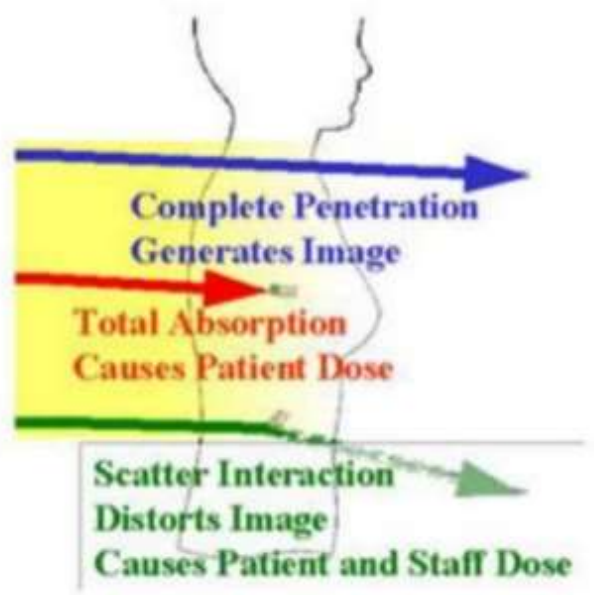


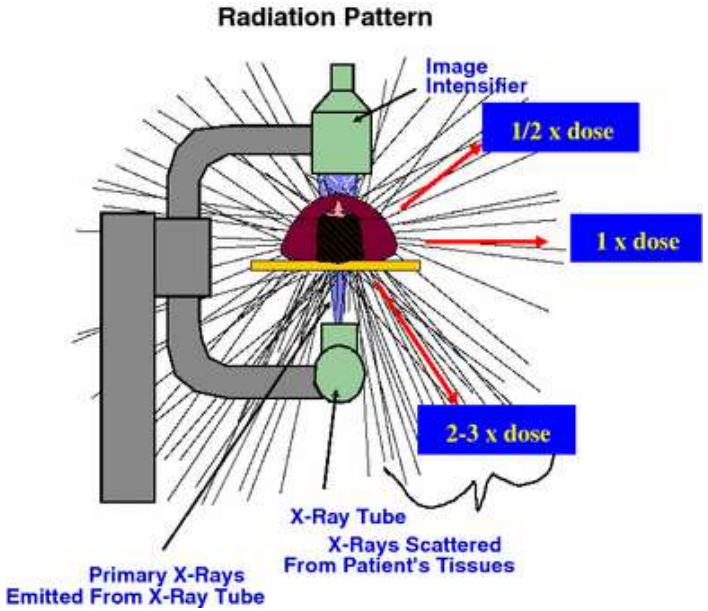
Dose Quantities



Radiation Sources

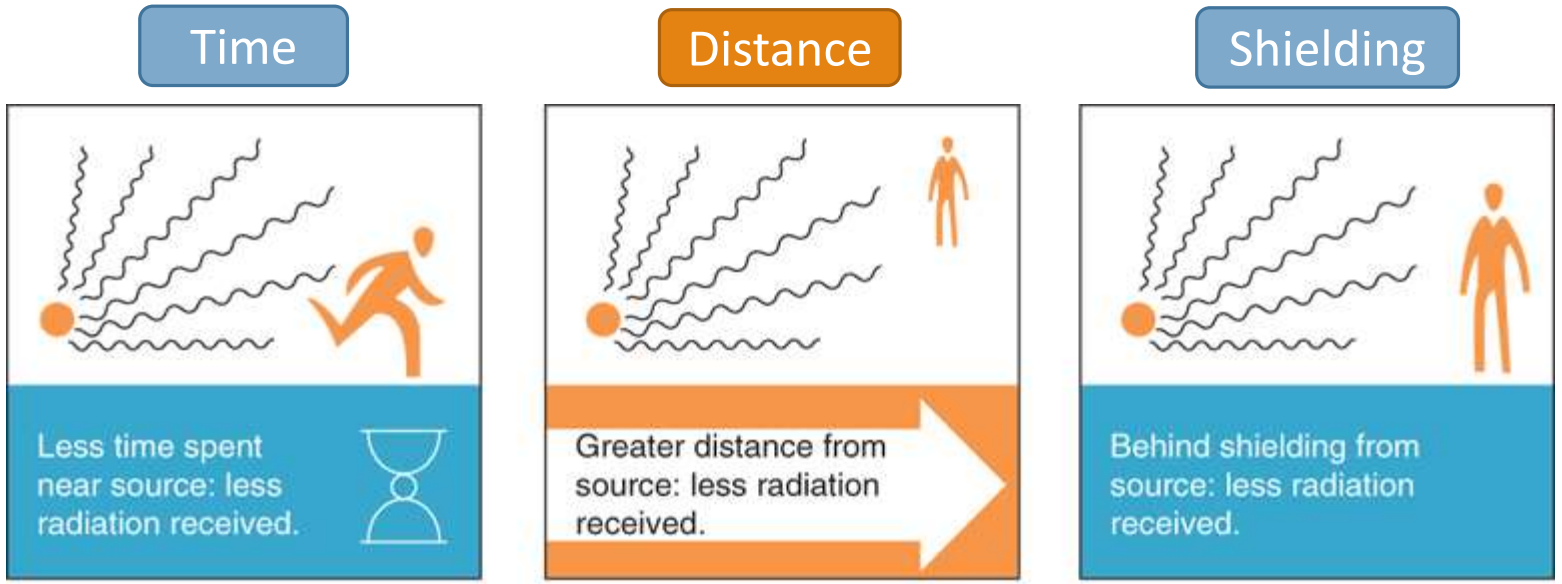
- For patients: radiation dose comes from the ***X-ray tube***
- For the medical personnel: radiation dose comes from the ***Patient***!
- Lowering the dose to the patient means lowering the dose to the staff





How to achieve Radiation Protection

The three basic principles of protecting yourself and others from radiation are:



Time

- total exposure time should be ***ALARA*** ➔ less exposure, less dose
- Fluoroscopy time is often used as an indication of patient dose, but the correlation is very poor ➔ fluoroscopy time should not be used as the only dose indicator

- Optimizing ‘time’ in an interventional procedure considers:
  - Number of images
  - Number of x-ray pulses per image
  - Number of retakes
  - Number of (ciné) runs and their duration (ciné dose is much higher than fluoro dose)
  - Frame rate (determine the minimum number of frames per second needed)

Time

is also the 'total ***X-ray Energy*** per pulse':

- System dose settings (high versus low dose level)
- Angulation of the beam (amount of tissue traversed)
- Investigation of new options of a system
- The correct use of filtration, grid, magnification views & collimation
- Working with specified (patient size optimized?) procedures
- Post processing

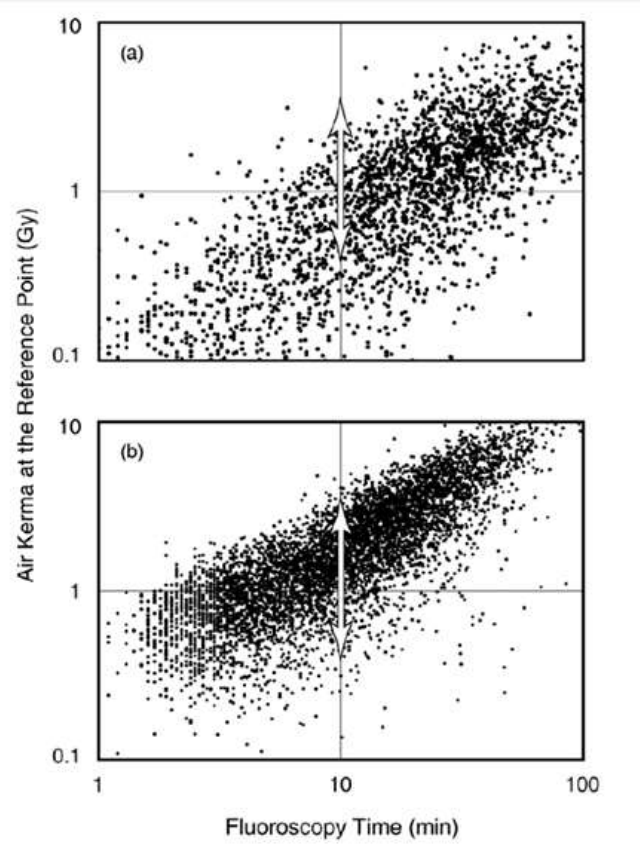


Fig. 2.2. Relationship between $K_{a,r}$ and fluoroscopy time for FGI procedures (Balter, 2008). Scatter plots of $K_{a,r}$ versus fluoroscopy time in minutes (F_{min}): (a) 2,100 noncardiac interventions; (b) 1,700 coronary-artery procedures. The linear regression equations ($K_{a,r}$ as a function of F_{min}) and the regression coefficients (R^2) are: for (a) $K_{a,r}=0.41+0.037F_{min}$, R^2 = 0.50; for (b) $K_{a,r} = 0.53 + 0.12\ F_{min}$, $R^2 = 0.68$. Data points below 1 min or above 100 min are not displayed but were used in the regressions. The white arrows demonstrate that $K_{a,r}$ varies by more than a factor of 10 at most fluoroscopy times.

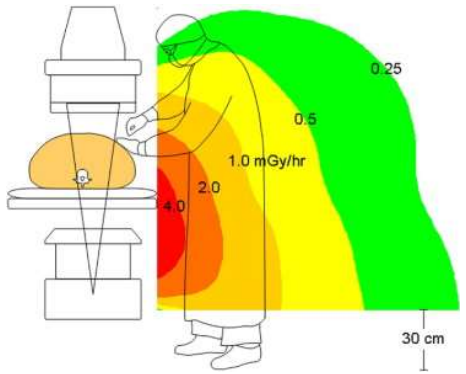
Time

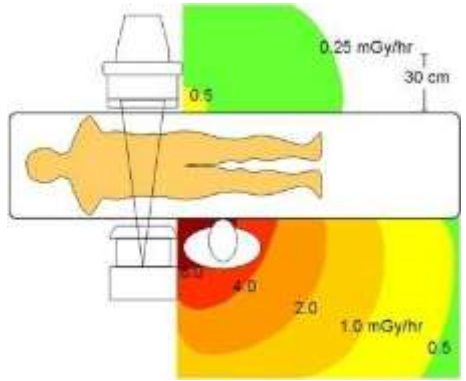
is also '***Human Efficiency***':

- Technical and practical knowledge on proper operation of a system and dealing with error messages
- Training of the personnel (example: find and apply procedure specific programs)
- Fluoroscopy only to observe objects or structures in motion.
- Review the last-image-hold for study, consultation, or education (as opposed to additional fluoroscopic exposure)
- The use of dose reducing actions
- Team work, team spirit

Distance

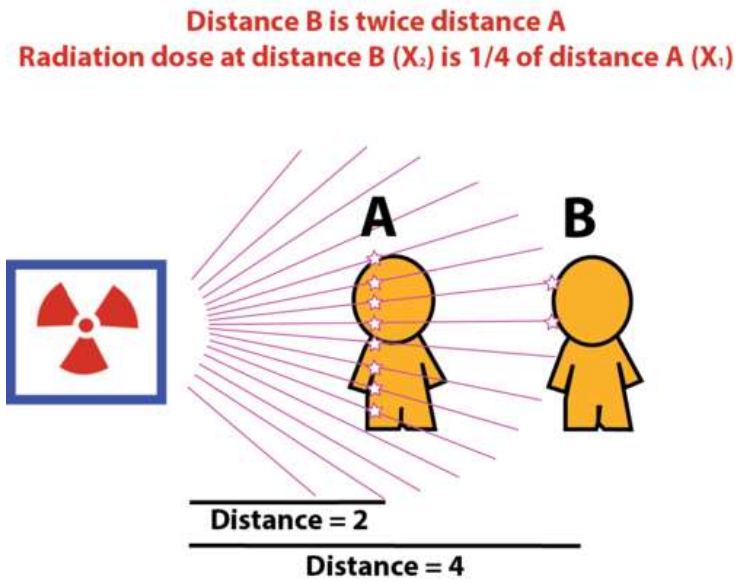
- Know when the beam is on
- Check where the tube is… check where the x-rays enter the patient and will be scattered
- The patient is the source of radiation. KEEP distance!
- Put the tube under the table
- Operators should avoid a place next to the tube
- Step back from the patient, preferably behind shielding
- Don’t slouch over the patient, but stand upright





Distance

- Keep your hands out of the radiation field
- Put the detector as close as possible to the patient
- If not needed in the room, leave the room. Try not to be standing next to the patient
- Use power injectors for contrast material injections when feasible
- Ergonomics in the room
- Place the monitors away from the x-ray source
- Analysis of danger



Shielding

Lead shielding is critical for the protection of the medical personnel

- Lead apron, thyroid shield, eyewear (gloves, cap, gonad shield)
- Ceiling mounted lead shield
- Table side shields
- Protective garments stop approximately 95% of scatter radiation
- Check your aprons for cracks regularly

Not even the best Pb is going to free you from needing to be careful with radiation
Responsibility of the owner of the facility or the MD to create a radiation awareness culture

Shielding

- Wearing this heavy lead apron has proven to lead to an increase in orthopedic back pain issues among interventionalists, *"the interventionalist disc disease"*

- A Possible solution to this problem is the:

Zero-Gravity Radiation Protection System

It uses a ceiling suspended gantry system to support a walk-in, lead-lined suit that eliminates the weight of lead aprons being placed on the body of the interventionalist. The gantry allows for smooth movement along the X, Y, Z axis.

Some practical tips

Some practical tips

Patient Position

- The patient should be placed away from the radiation source to lower the ***skin dose***

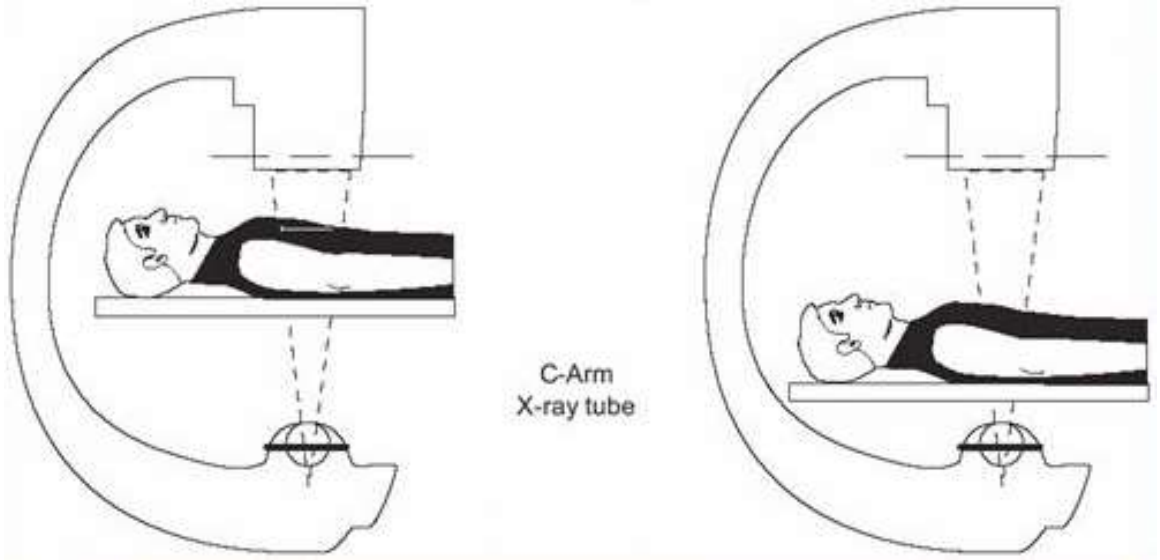
- The image detector should be placed close to the patient to lower the necessary dose
  ➔ less geometric blurring

- The tube should always be positioned under the table (under couch configuration)
  ➔ less scatter towards the personnel's eyes

- Keep the patient's extremities out of the beam

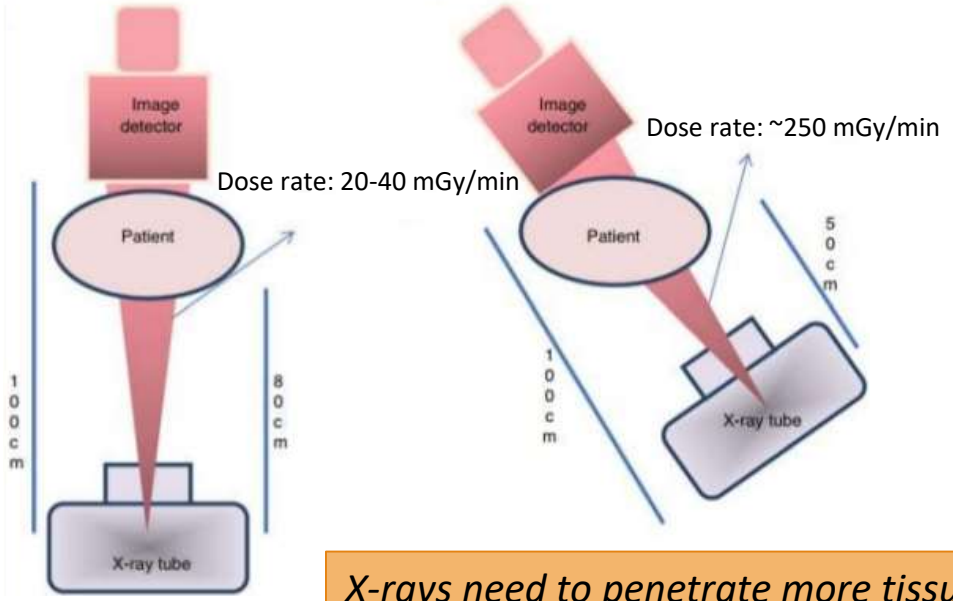
CORRECT TECHNIQUE
Low exposure and good image quality

INCORRECT TECHNIQUE
High exposure and blurred image

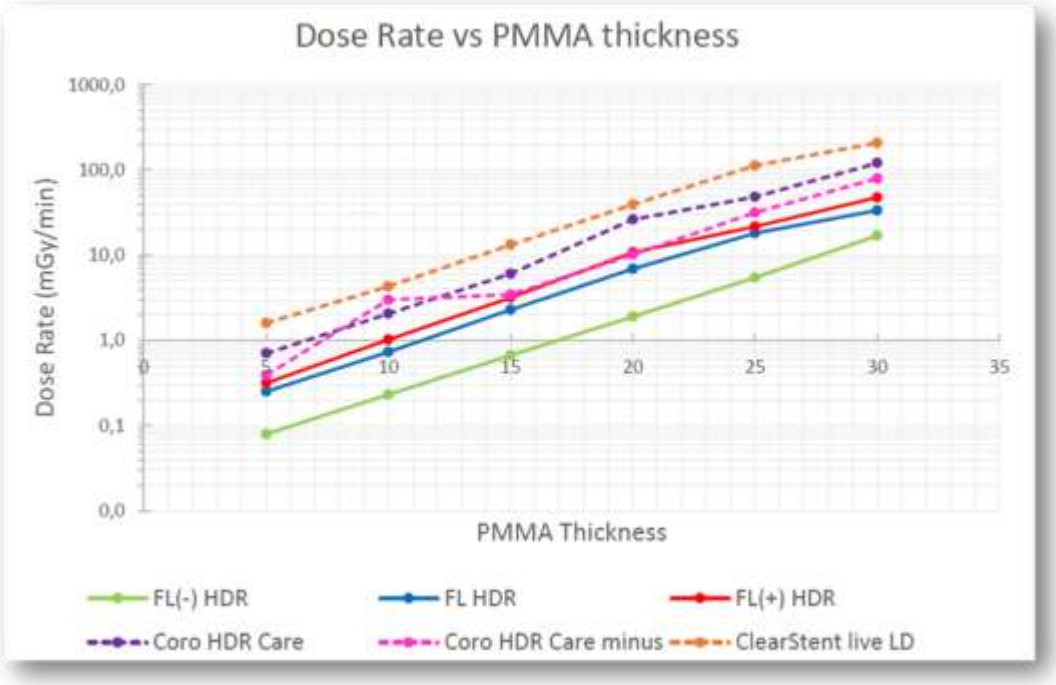


Tube Angulation

- The use of ***steep*** angulations should be minimized and used only if necessary
- Each 3 cm additional tissue ***doubles*** the dose to the patient (factor of ~10 each 10 cm)



X-rays need to penetrate more tissue and the source to skin distance is reduced



Tube Angulation

- Using small angulations actually has the potential to reduce the peak skin dose of the patient
- Moving the X-ray beam to different areas of the patient's body during the procedures lowers the peak skin dose
- Good practice: every ***30 minutes***, change the beam angle

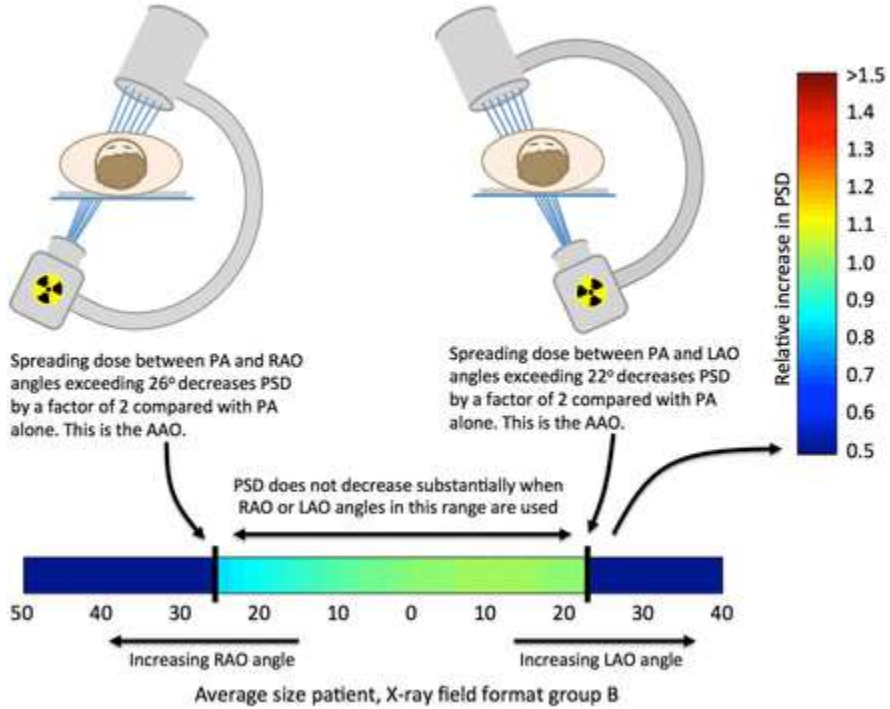


Figure 1 from: Pasciak AS, Bourgeois AC, Jones AK
C-arm rotation as a method for reducing peak skin dose in interventional cardiology, *Open Heart* 2014

Magnification

- Magnification will increase the patient dose (beam energy is condensed to a smaller area)

- Use the largest Field of view (FOV) possible for the procedure being performed. The difference in skin dose between the larger FOVs and the smallest is a factor of ~4

- In modern systems, there is a "***Live Zoom***" feature without additional radiation and without significant degradation of the image

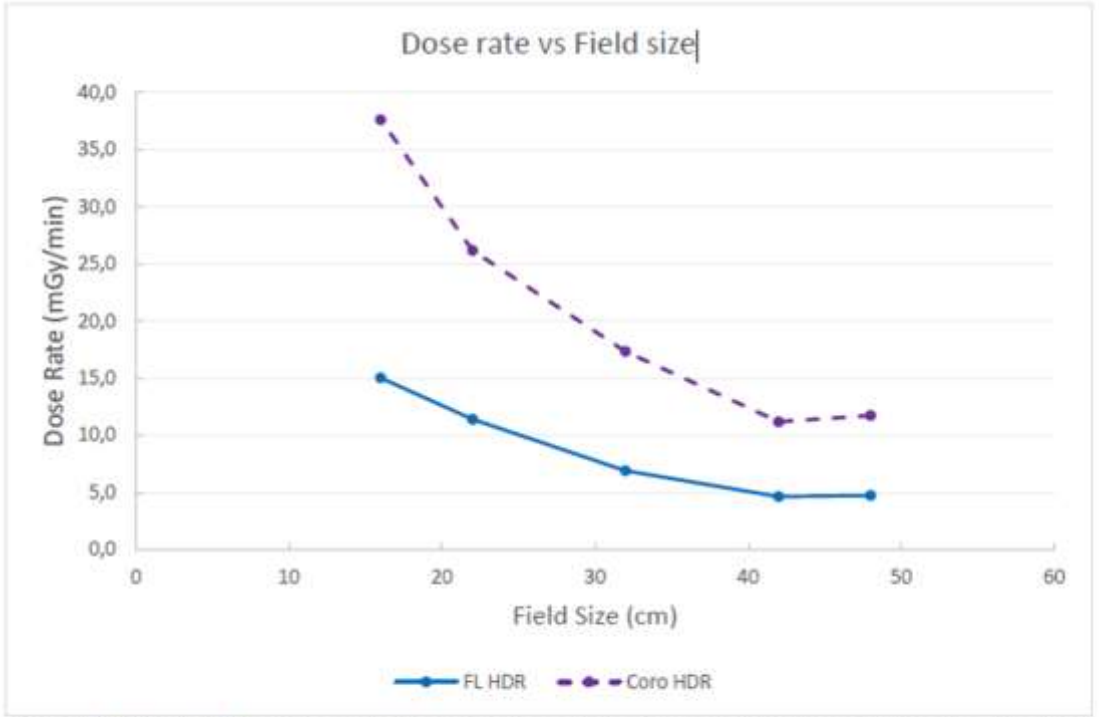


Figure IV. This graph shows how the dose rate (measured at the table) varies as a function of the field size for FL HDR and Coro HDR. As expected the dose rate drops with increasing field size and the fluoroscopy program lies well below the acquisition one.

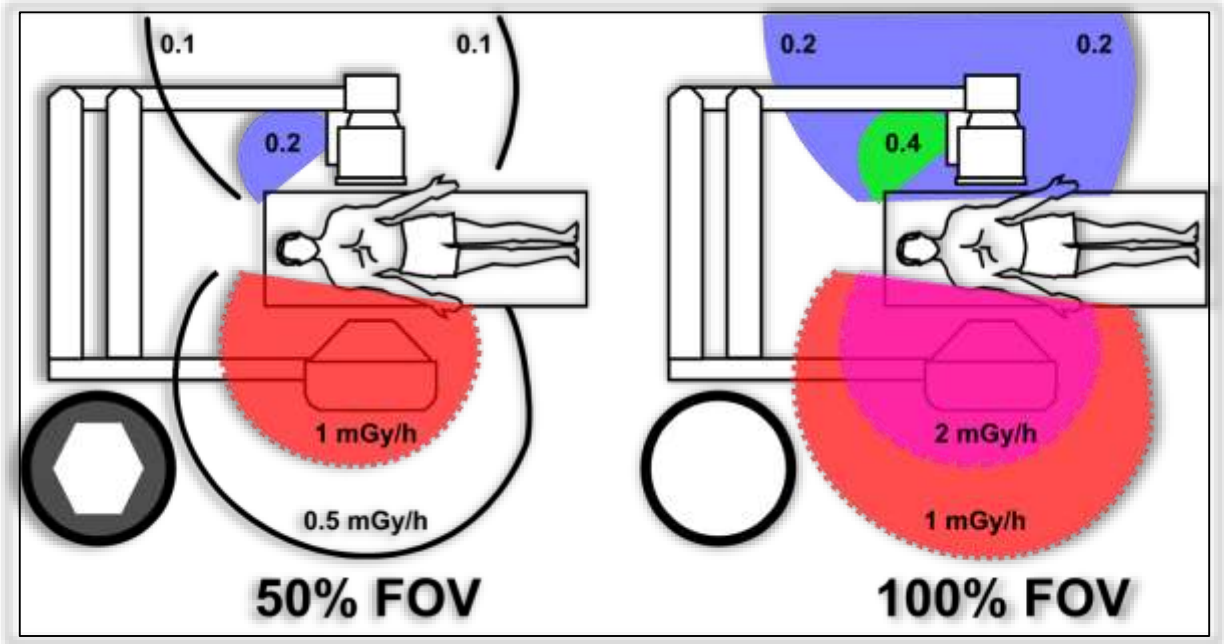
Collimation

A ‘collimator’ is an adjustable lead shutter located at the exit of the X-ray source that can be closed down to limit the irradiated area

- Appropriate collimation should be used for the imaging task

➔ this lowers both the patient’s dose and the staff’s

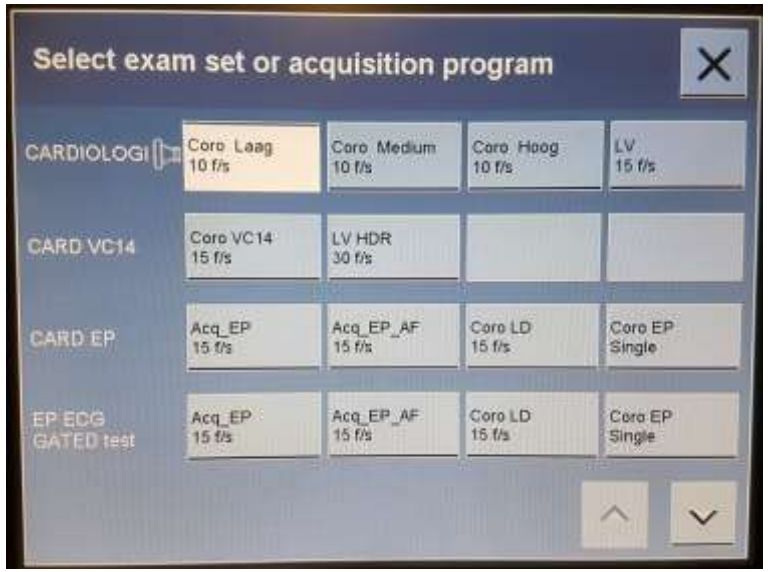
- Modern systems should be equipped with virtual collimation

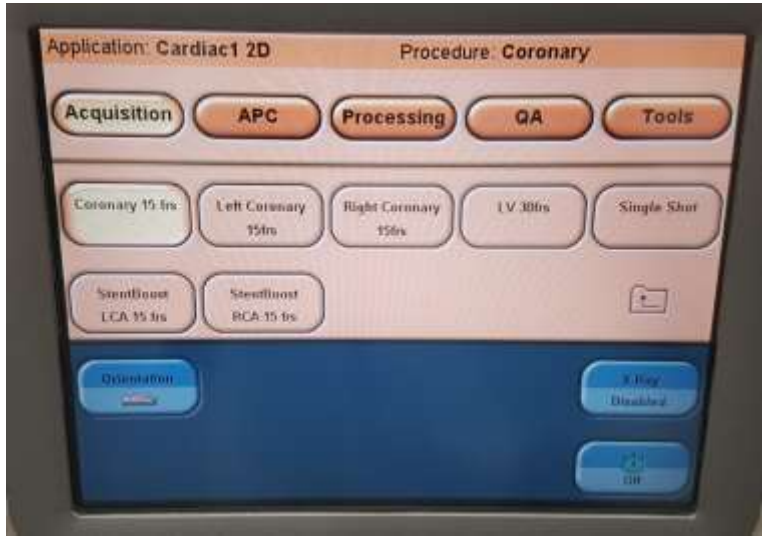


System Settings

- It is important to get to know your system and its options
- Make sure to use the lowest dose setting when possible
- Talk with the manufacturer/technician to set the initial dose setting to ‘low dose’
  ➔ increase when necessary instead of lowering when possible (less chance to forget)
- Use the proper frame rate, lower where possible
- Use the proper acquisition program
- Make sure when buying a new system that it has proper filtration
  ➔ Cu filters out the low energy X-rays, lowering skin dose

Select the proper program

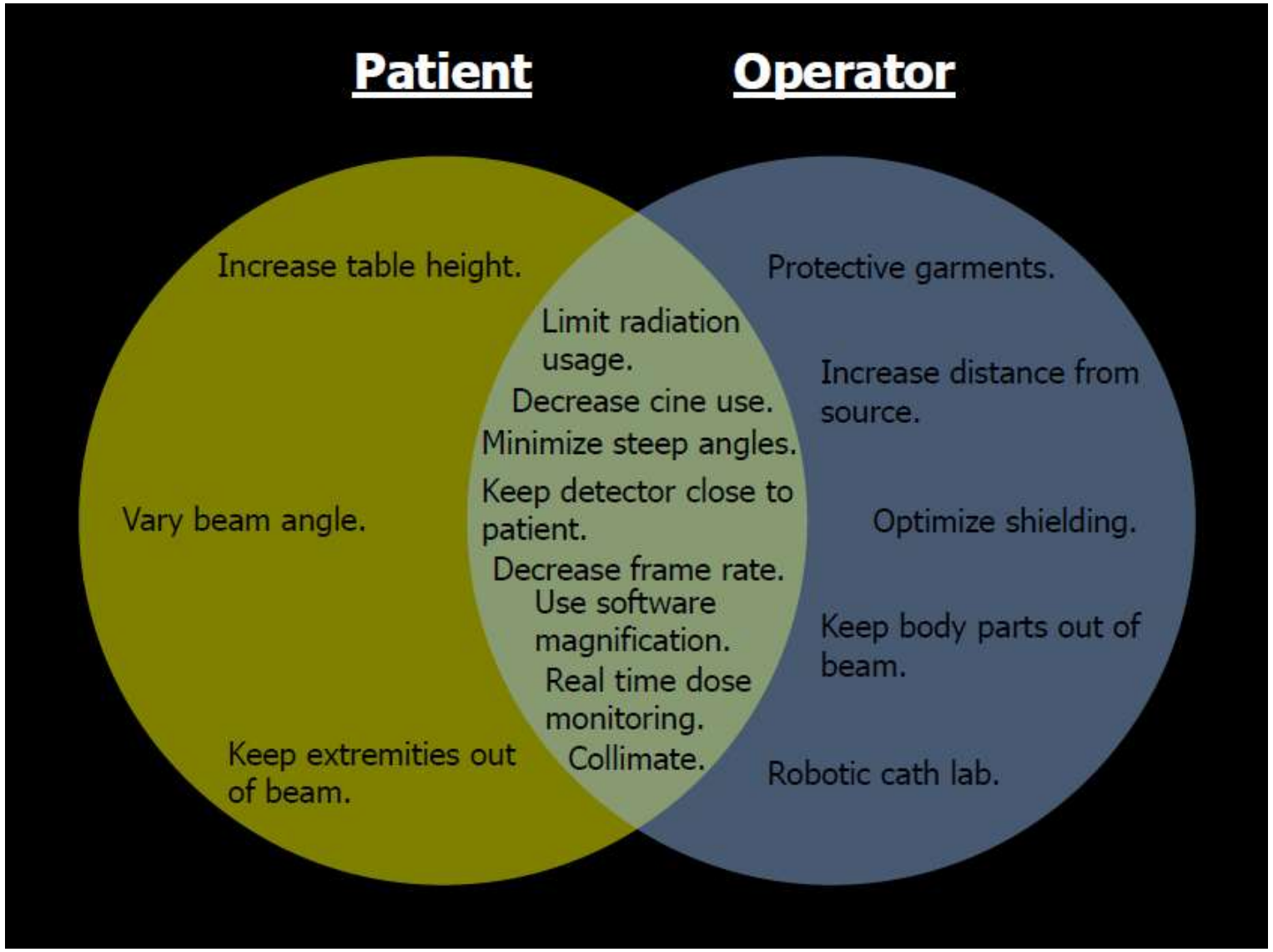




Select the proper Dose level

Select the proper Frame rate

Summary


Patient
Operator
Increase table height.
Vary beam angle.
Keep extremities out of beam.
Limit radiation usage.
Decrease cine use.
Minimize steep angles.
Keep detector close to patient.
Decrease frame rate.
Use software magnification.
Real time dose monitoring.
Collimate.
Protective garments.
Increase distance from source.
Optimize shielding.
Keep body parts out of beam.
Robotic cath lab.

Dose Monitoring

- Recommendations stated in NCRP 168:

Recommendation 14

Interventionalists *shall* be responsible for patient radiation levels during FGI procedures and *shall* ensure that radiation dose accumulation is continuously monitored during the procedure.

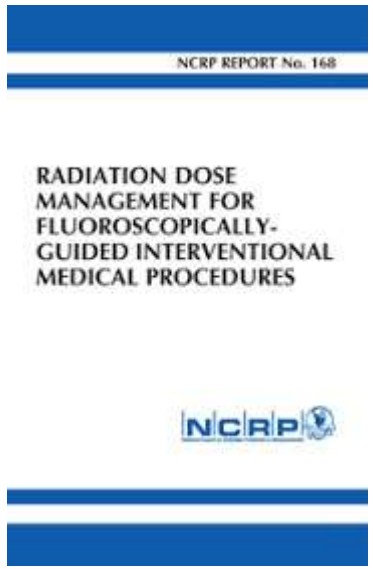
Recommendation 15

Patient dose data *shall* be recorded in the patient's medical record at the conclusion of each procedure. This *shall* include all of the following that are available from the system: $D_{skin,max}$, $K_{a,r}$, P_{KA}, fluoroscopy time, and number of fluorographic images.

Recommendation 19

Facilities *shall* have a process to review radiation doses for patients undergoing FGI procedures.

Advisory data based on measured dosimetric quantities (in particular P_{KA} or $K_{a,r}$ to manage overall performance, and $K_{a,r}$ to manage deterministic effects) *should* be used for quality assurance purposes.

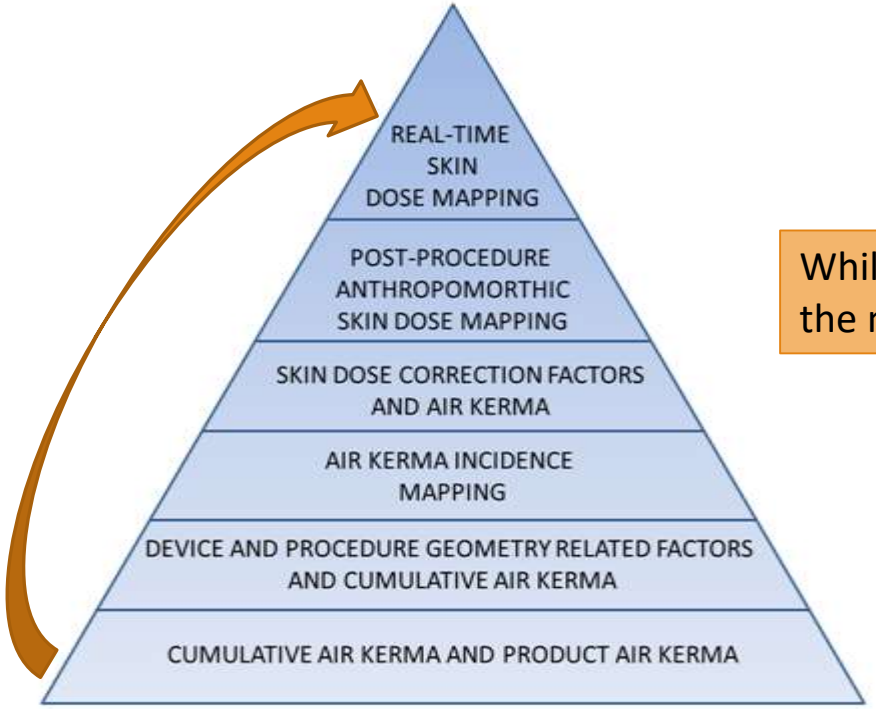


Framerate
Dose mode
Fluoro time

DAP
Cumulative K_a

Dose Monitoring Pyramid

- Monitoring DAP and $K_{a,r}$ is only scraping the bottom of the possible options:



While the medical team addresses the patients, the medical physicist could climb the pyramid!

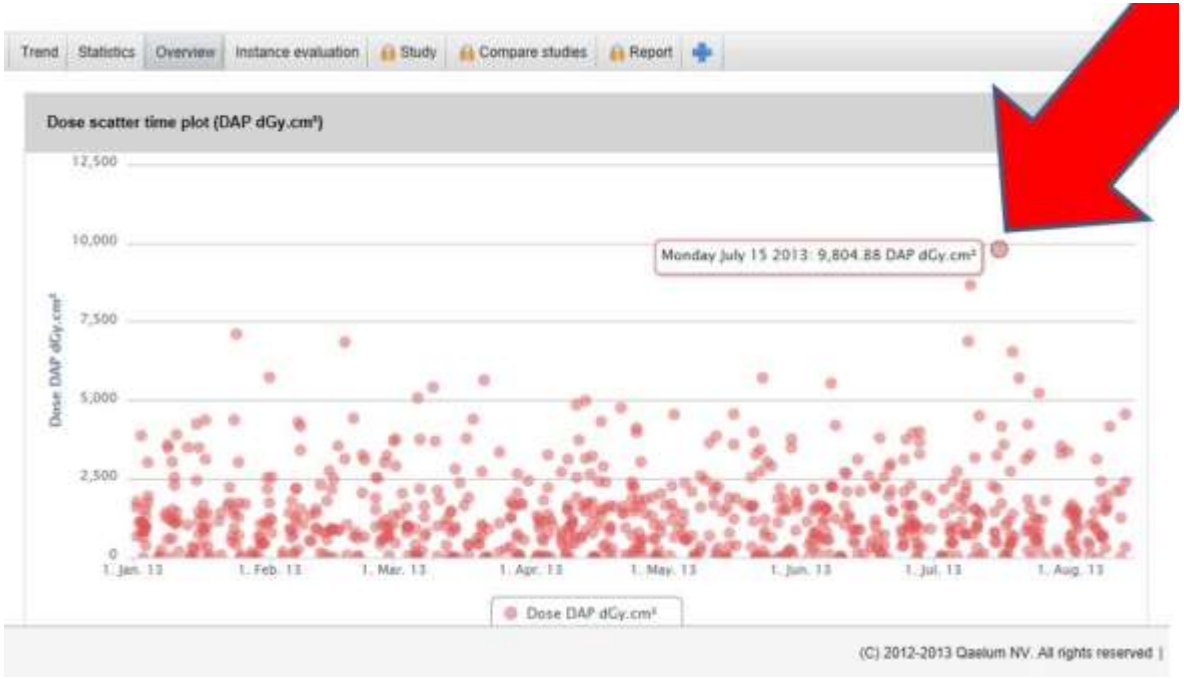
Copied from AAPM TG246

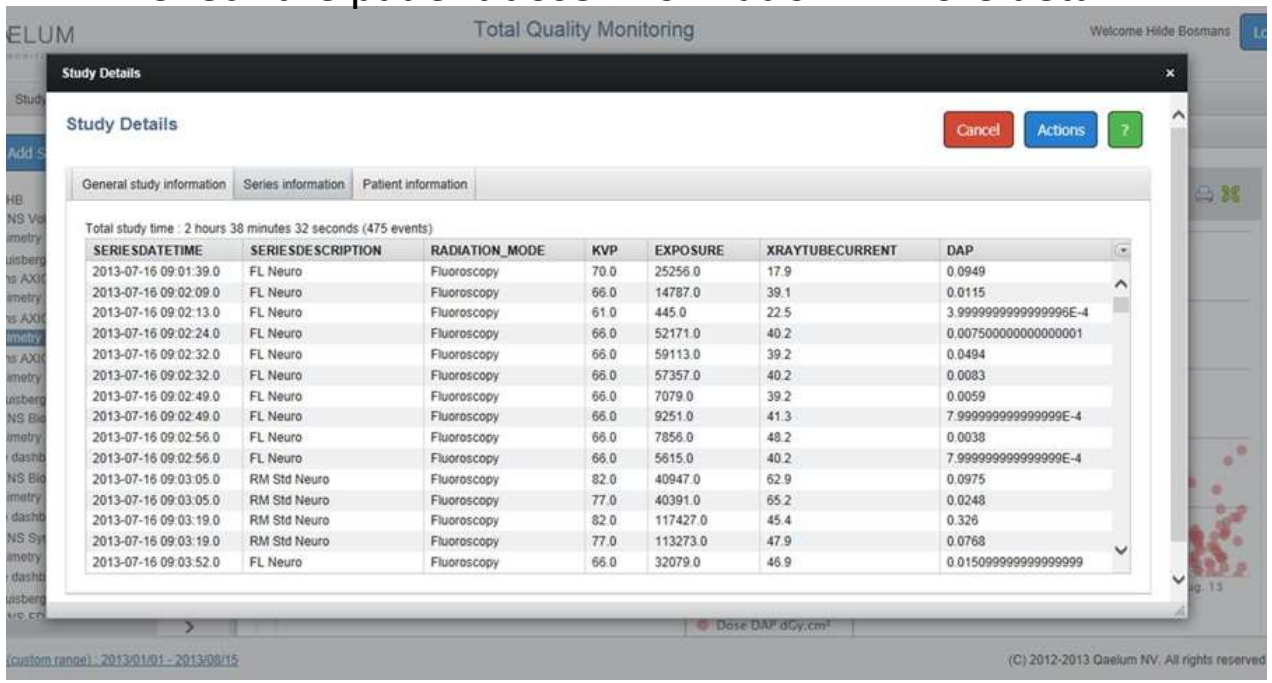
Dose Monitoring with Skin Dose Mapping

- Skin dose mapping used to be extremely labour intensive and not feasible on a per patient basis. Tools are now available to monitor patient dose online or quickly after the procedure
- These tools allow the radiologists and medical physicists to improve patient follow up
- Dose management for patients with repeated exposures is of great importance for radiation protection purposes ➔ help with risk analysis and locating irradiated skin
- Peak skin dose mapping predicts possible deterministic effects
- Skin Dose Mapping (real-time or post processed) is of great importance to trigger optimization actions. It may show the need !

Dose Monitoring

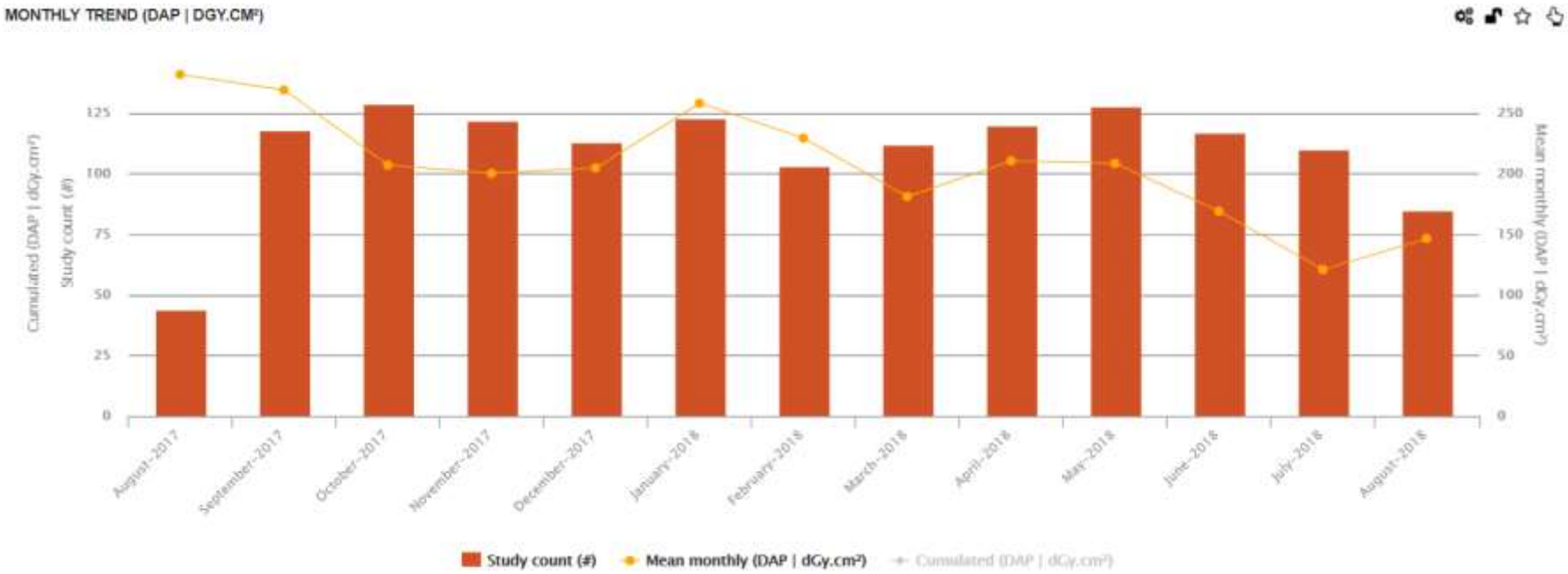
Check the patient dose information in more detail





Courtesy TQM by Qaelum NV

Analyze trends



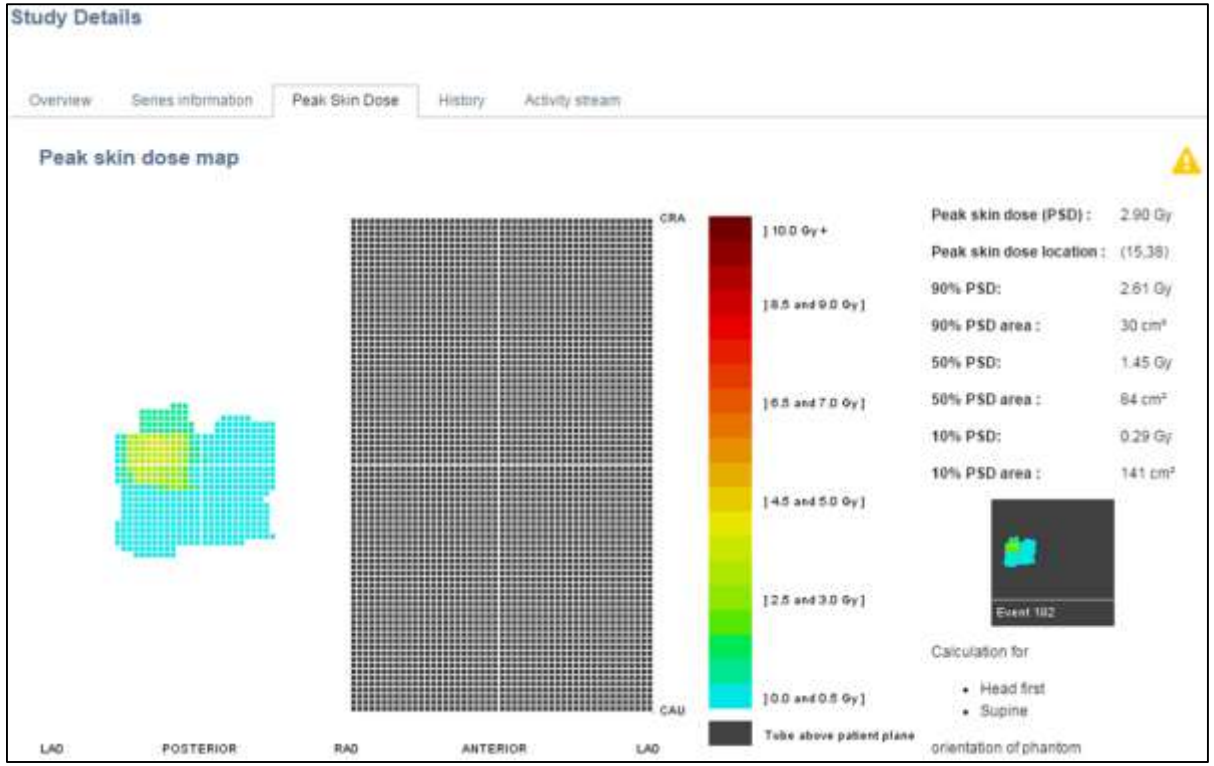
Check DRLs per system and compare with others

STATISTICS OVERVIEW (STUDY DESCRIPTION - DAP | DGY.CM²) 9 rows .

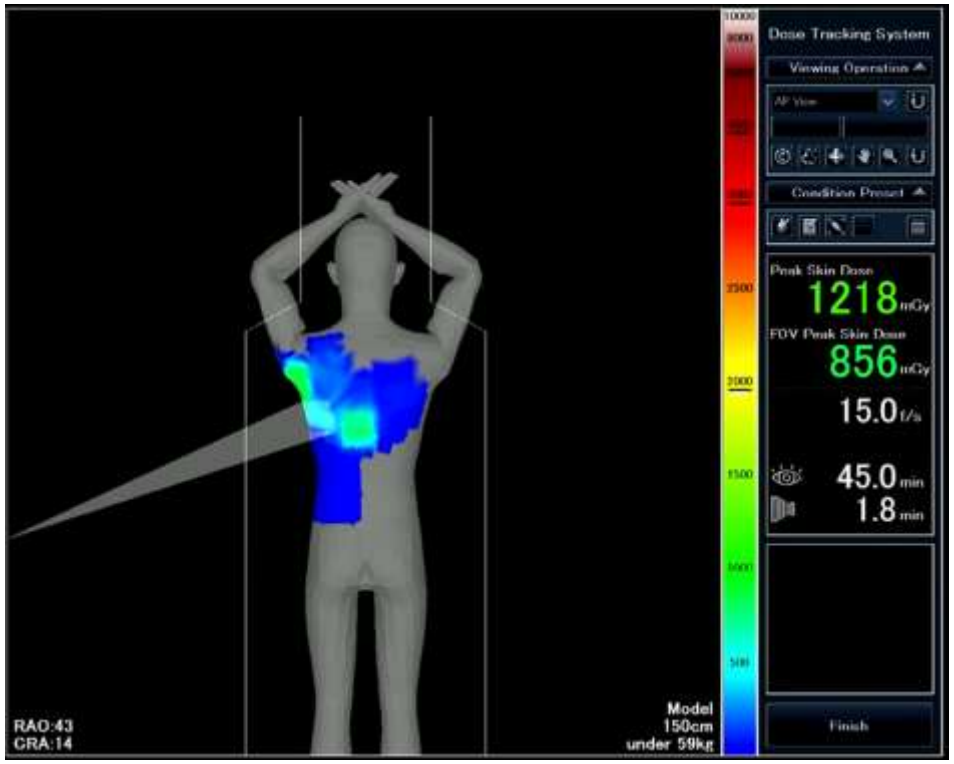
STUDY DESCRIPTION	COUNT (#)	RELATIVE COUNT (%)	AVG EVENT COUNT	MIN	MAX	MEAN	PERC. (10)	PERC. (25)	MEDIAN	PERC. (75)	PERC. (90)
Coronary^Bioptie Re cathé	40	2.81 %	14.03	2.19	544.01	64.76	2.74	6.8	18.27	73.67	239.44
Coronary^Diagnostic Coronary Catheterization	993	69.73 %	40.09	0.09	2.81E3	252.19	9.65	57.53	160.19	326.07	582.03
Coronary^Li Re hart	30	2.11 %	44.3	41.06	723.84	253.03	65.19	117.7	175.43	347.42	563.06
Coronary^Rechter cathé	328	23.03 %	15.99	0.05	1.75E3	64.96	2.16	4.9	12.9	40.93	184.65
Electrophysiology^Electrophysiology study	5	0.35 %	47.2	1.11	217.86	114.8	1.11	11.26	119.59	215.96	217.86
N/A	4	0.28 %	36.5	26.71	175	85.6	26.71	33.78	70.35	152.68	175
Pediatric^Pediatric Cardiac Intervention	2	0.14 %	97	0.36	3.83E3	1.91E3	0.36	0.36	1.91E3	3.83E3	3.83E3
Peripheral^Diagnostisch	3	0.21 %	6.67	0.56	1.64	1.06	0.56	0.56	0.98	1.64	1.64

Courtesy TQM by Qaelum NV

Skin Dose Mapping



Courtesy TQM by Qaelum NV



Courtesy DTS by Canon Medical systems

Trigger levels and patient follow up

- Trigger levels should be set up in order to prevent skin damage to the patient
  ➔ a typical threshold value of 2-3 Gy (skin dose) can be found in literature

TABLE 4.7–*Suggested values for first and subsequent notifications and the SRDL.*

Dose Metric	First Notification	Subsequent Notifications (increments)	SRDL
$D_{skin,max}$	2 Gy	0.5 Gy	3 Gy
$K_{a,r}$	3 Gy	1 Gy	5 Gy[a]
P_{KA}	300 Gy cm^2 [b]	100 Gy cm^2 [b]	500 Gy cm^2 [b]
Fluoroscopy time	30 min	15 min	60 min

[a]See additional discussion concerning the value 5 Gy in Section 4.3.4.2.
[b]Assuming a 100 cm^2 field at the patient's skin. For other field sizes, the P_{KA} values should be adjusted proportionally to the actual procedural field size (*e.g.*, for a field size of 50 cm^2, the SRDL value for P_{KA} would be 250 Gy cm^2).

Source NCRP 2010

Table 1: Trigger levels in terms of total KAP, corresponding to a maximal skin dose of 2 Gy, for several interventional procedures in Belgian hospitals.

TRIGGER LEVELS		KAP Gy.cm²
TIPPS & chemo embolisations of the liver		330
Cerebral embolisations	Mono-plane	175
	Bi-plane	240
RF ablations		180
Biliary drainages	Conventional	160
	PTC	180
Embolisations vena spermatica		270
ERCP		295
CA & PTCA		125

Courtesy: L. Struelens, on behalf of the TRIR partners, unpublished data. Text will be resubmitted soon.

Struelens L, Phys Med. 2014 Dec;30(8):934-40

Patient Follow Up

- Recommendations stated in NCRP 168:

Recommendation 16

If a substantial radiation dose level (SRDL) (Table 4.7 and Section 4.3.4.2) is exceeded while performing an FGI procedure, the interventionalist *shall* place a note in the medical record, immediately after completing the procedure, that justifies the radiation dose level used.

Recommendation 17

If an SRDL is exceeded for an FGI procedure, the patient and any caregivers *should* be informed, prior to discharge, about possible deterministic effects and recommended follow-up.

If fluoroscopy time exceeds the SRDL, but other measured dose metrics do not exceed the SRDL, patient information and follow-up *may not* be necessary.

- Steve Balter: *"with obese patients it is good clinical practice that threshold values for deterministic effects are sometimes exceeded.*
  It means obese patients are treated properly.
  Skin injuries should however never be a post procedural surprise"

Diagnostic Reference Levels

- A DRL is a tool used to aid in optimization of protection in the medical exposure of patients for diagnostic and interventional procedures
- Reference levels are typically set at the 75th (and 25th) percentile of the median dose distribution from a survey, conducted across a broad user base using a specified dose measurement protocol
- Diagnostic reference levels are supplements to professional judgment and do not provide a dividing line between good and bad medicine. They apply only to medical exposure not public or occupational ➔ ***Not a dose limit!***
- They represent the dose level at which an investigation of the appropriateness of the dose should be initiated ➔ ***Too high or too low***
- Dose surveys should be repeated periodically to establish new reference levels
- The ICRP 135 contains many recommendations on establishing effective DRL protocols

Personal Dosimetry

- Patients have their DAP value, you have your dosimeter! The high occupational exposures in interventional radiology require the use of robust and adequate monitoring arrangements for staff
- Personal dosimeters are typically thermoluminescent dosimeters (TLDs)
- It is recommended (sometimes obliged) to wear ***two dosimeters:***
  1. Under-apron worn at breast or waist level ➔ gives an estimate of effective dose and confirms the lead apron is being worn (properly)
  2. Over-apron worn at the collar level ➔ provides an estimate of the eye lens dose
- The monitoring period should be one month, and should not exceed three months

Real Time Personal Dosimetry

- Real time radiation dose monitoring in the Cath lab enables staff to see their level of exposure any time and can alert them when their levels are spiking
- Can still be useful even when not used in daily practice:
- Active, electronic personal dosimeters have proven useful for optimization monitoring, for ***educational purposes***, for special studies of dose by procedure, and for specific aspects of a procedure

Quality Assurance

Quality Assurance

- World Health Organization (1982):

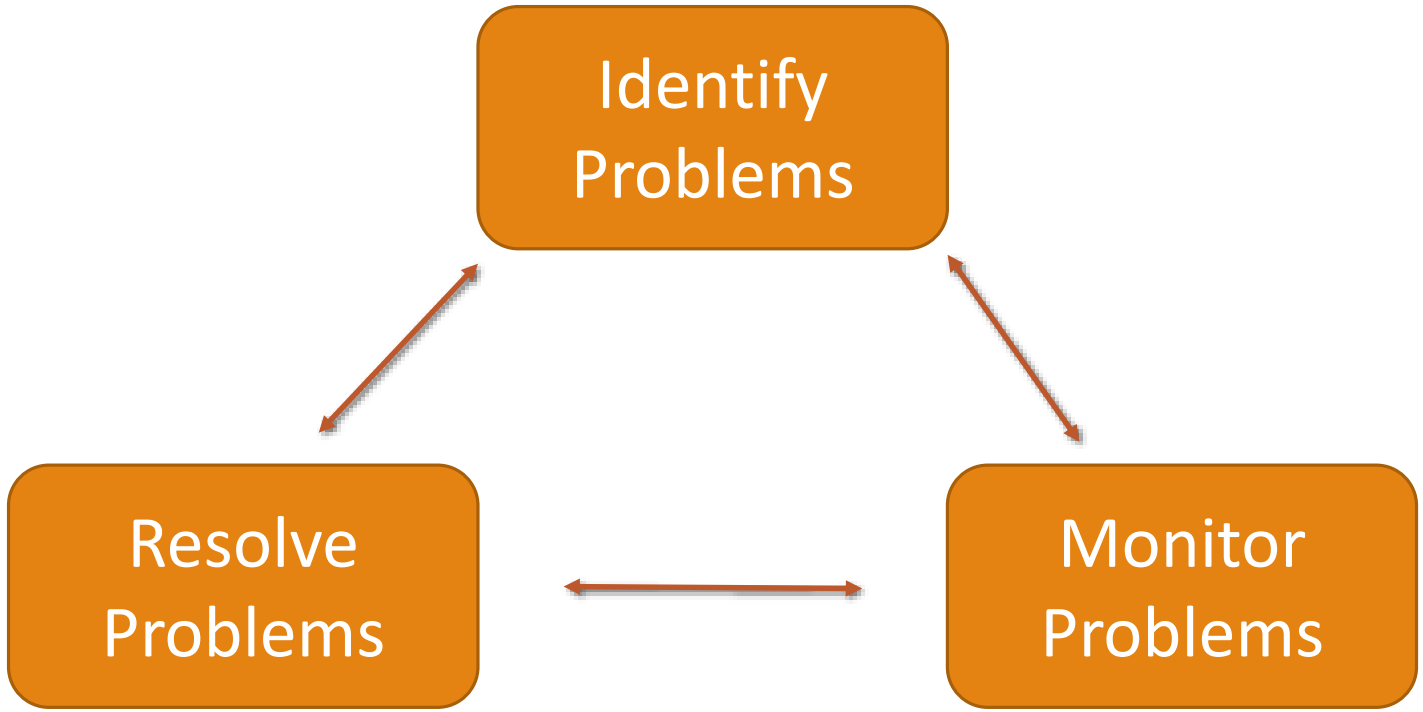
" Quality Assurance is an ***organized effort*** by the staff operating a facility, to ensure that the diagnostic images produced by the facility are of sufficient high quality so that they consistently provide adequate diagnostic information at the lowest possible cost and with the least possible exposure of the patient to radiation. **"**

- Council Directive 2013/59/Euratom:

" Quality Assurance (QA) means all those ***planned and systematic actions*** necessary to provide adequate assurance that a structure, system, component or procedure will perform satisfactorily in compliance with agreed standards. "

- Quality control is a part of quality assurance

Quality Assurance



Quality Assurance

- Developing a successful Quality Assurance program is an essential part of radiological protection
- This is a significant undertaking in need of strong leadership and collaboration of staff
- Some recommendations of the ICRP 120:

✓ *The two basic objectives are to evaluate patient radiation dose periodically and to monitor occupational radiation dose for workers*

✓ *Training in radiological protection (both initial and retraining) should be included for all staff involved in interventional procedures*

✓ *A radiologist/cardiologist should have management responsibility for the quality assurance program aspects of radiological protection and should be assisted by a medical physicist*

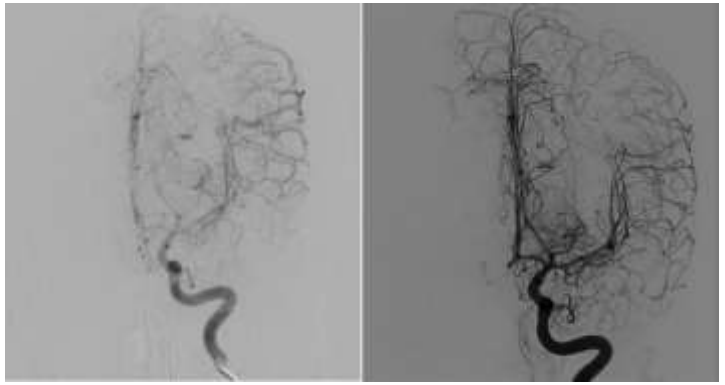
✓ *A senior interventionalist and a medical physicist should be included in the planning for and installation of a new interventional fluoroscopy laboratory or upgrade of existing equipment*

Quality Assurance

- ✓ *The QA program should include patient dose audits and comparison with diagnostic reference levels*
- ✓ *Periodical evaluation of image quality and procedure protocols should be included in the QA program*
- ✓ *The QA program should ensure the regular use of personal dosimeters and include review of all abnormal dose values*
- ✓ *The QA program should establish a trigger level for individual clinical follow-up when there is a risk of radiation induced skin injuries*
- ✓ *Patient dose reports should be produced at the end of procedures, archived and recorded in the patients medical record*

Future Technology

- Many solutions are being developed (or already exist) to reduce radiation exposure in the Cath lab:
  - Active dose monitoring in real time
  - Real time skin dose mapping
  - Zero gravity radiation protection systems
  - Robotic navigation systems (operator can sit behind lead glass)
  - Advanced Image processing, lowering the dose needs
  - ADRC optimization
  - Hybrid systems to increase work flow efficiency



- Example: Angio-MR system designed for stroke patients

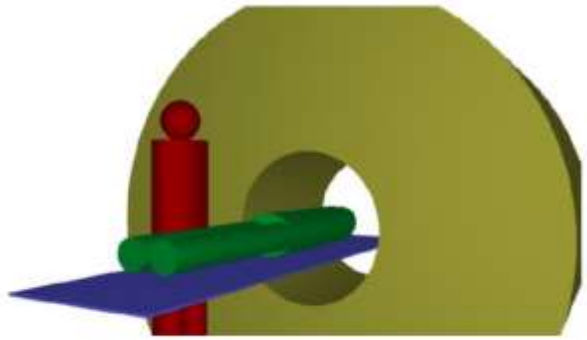
Future Technology

- Angio-MR system will have complete integration of the angio detector and X-ray tube in the MRI
  - No need to transport the patient between diagnosis and treatment ➔ huge benefit in time
  - More accurate information of the disease and better treatment since one can switch between MRI and Angio very fast
  - Immediate confirmation if the treatment is successful

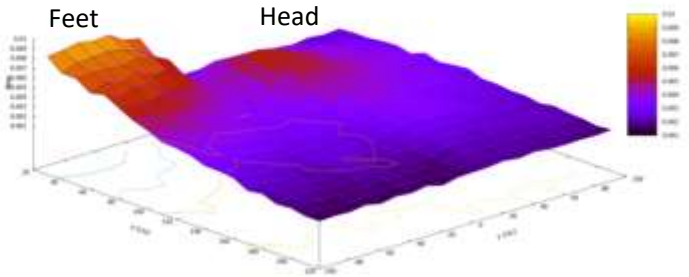
  ➔Better patient outcome

Future Technology & radiation protection

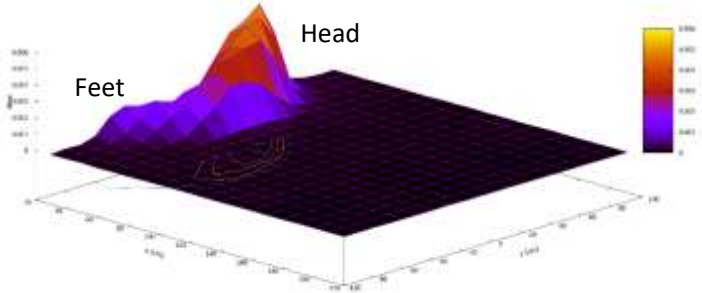
- Since patient is lying inside an MRI bore, there will be much less scatter radiation towards the staff
  ➔ perhaps no need of heavy lead aprons or ceiling mounted lead shields
- Using input from MRI, less fluoroscopy time needed ?
- Increased distance from the patient ?



Scatter Conventional C-arm



Scatter Angio-MRI



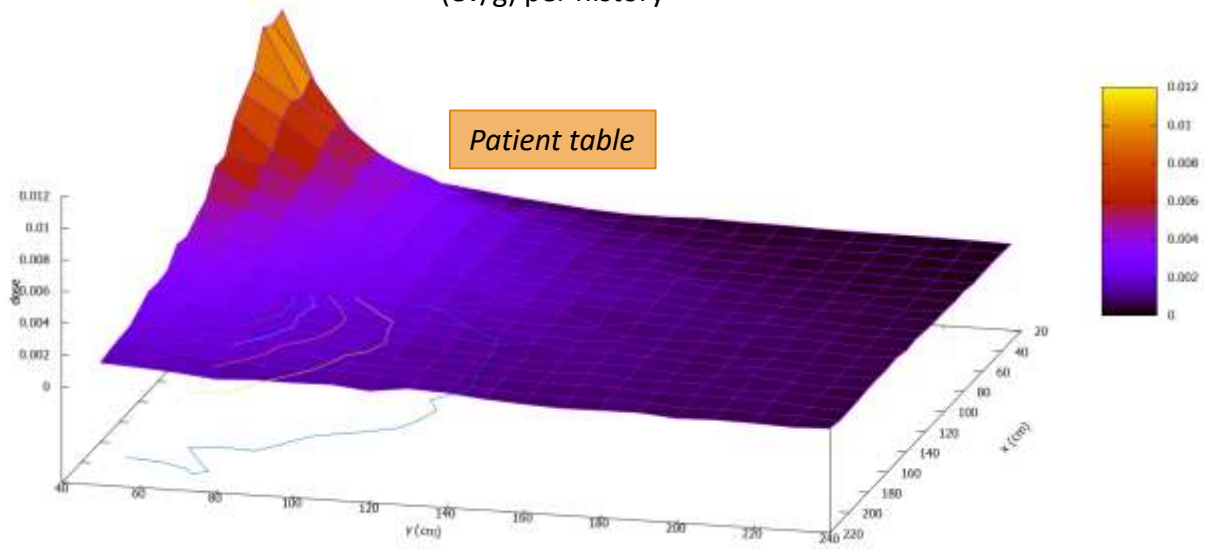
These are vertical planes orthogonal to the table located at the physicians position

Future technology & radiation protection

Conventional

3D Dose Distribution
(ev/g) per history

Patient table

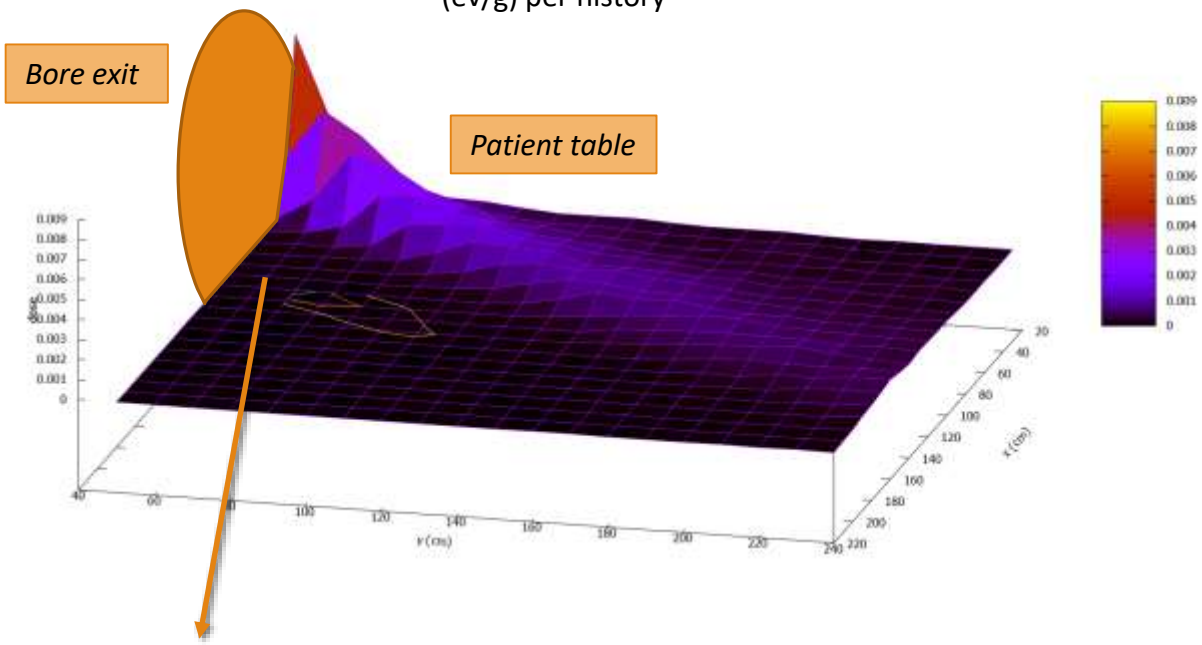


Angio-MRI

3D Dose Distribution
(ev/g) per history

Bore exit

Patient table



Shown are horizontal planes at the height of the table

Safe position for the interventionalist to stand

What is next?
Is the future bright ?

Thanks !!!!!!!


thank you
merci
danke
謝謝
gracias
teşekkür ederim
ngiyabonga
dziękuję
obrigado
bedankt
go raibh maith agat
dakujem
terima kasih
sukriya
kop khun krap
arigatô
grazie
tack
dank je
спасибо
рахмат
Баярлалаа
faafetai lava
kiitos
dankie
dhanyavad
hvala
mauruuru
köszönöm
nandri
nanni
bayarlalaa
gràçie
vinaka
blagodaram
спасибі
mersi
kia ora
barka
welalin
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misaotra
matondo
paldies
grazzi
mahalo
tapadh leat
хвал
asante
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tanemirt
rahmet
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তোমাকে ধন্যবাদ
감사합니다
xièxie
ευχαριστώ
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takk
shukriya
merci
мерси
trugarez