Radiation protection

in Cardiac Catheterization

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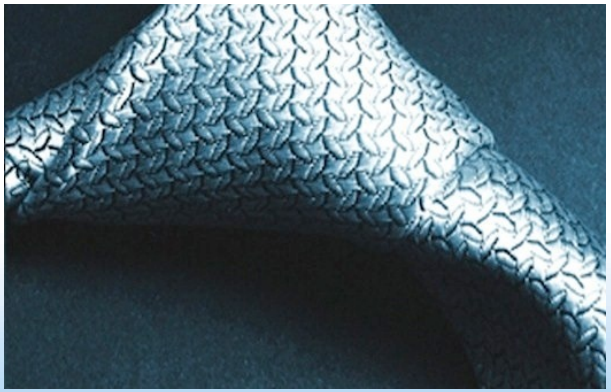
AEPC Junior Course in Cardiac Catheterization and Interventions - March 13th-15th, 2014 Linz-Austria

avoiding

„20 slides of Gray“

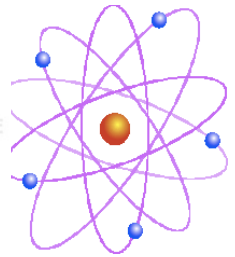


Who is Mr. Gray...?

SI unit for absorbed energy ..... Joule/kg
depending on the matter

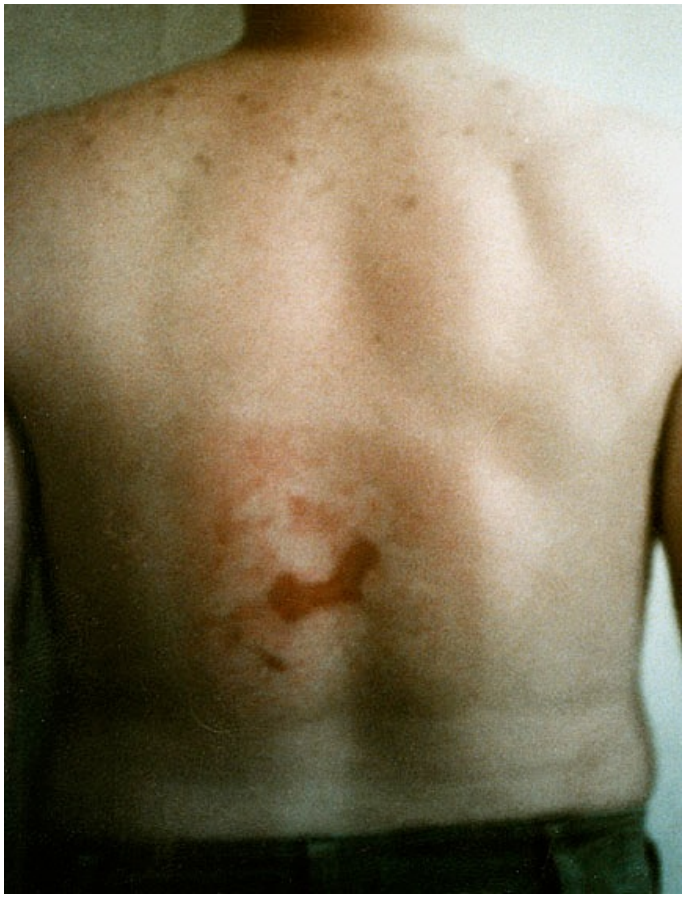
„Sex appeal“: .....Air-Kerma
emitted kinetic energy to air

--> simple technical quantity
--> **output**



Kerma is an acronym for "**k**inetic **e**nergy **r**eleased per unit **ma**ss", defined as the sum of the initial kinetic energies of all the charged particles liberated by uncharged ionizing radiation

Too much of Gray.....



results in damage!

Treshold for skin damage
is about

2 Gray
effective dose

Who is Ms. Sievert „Steele“?

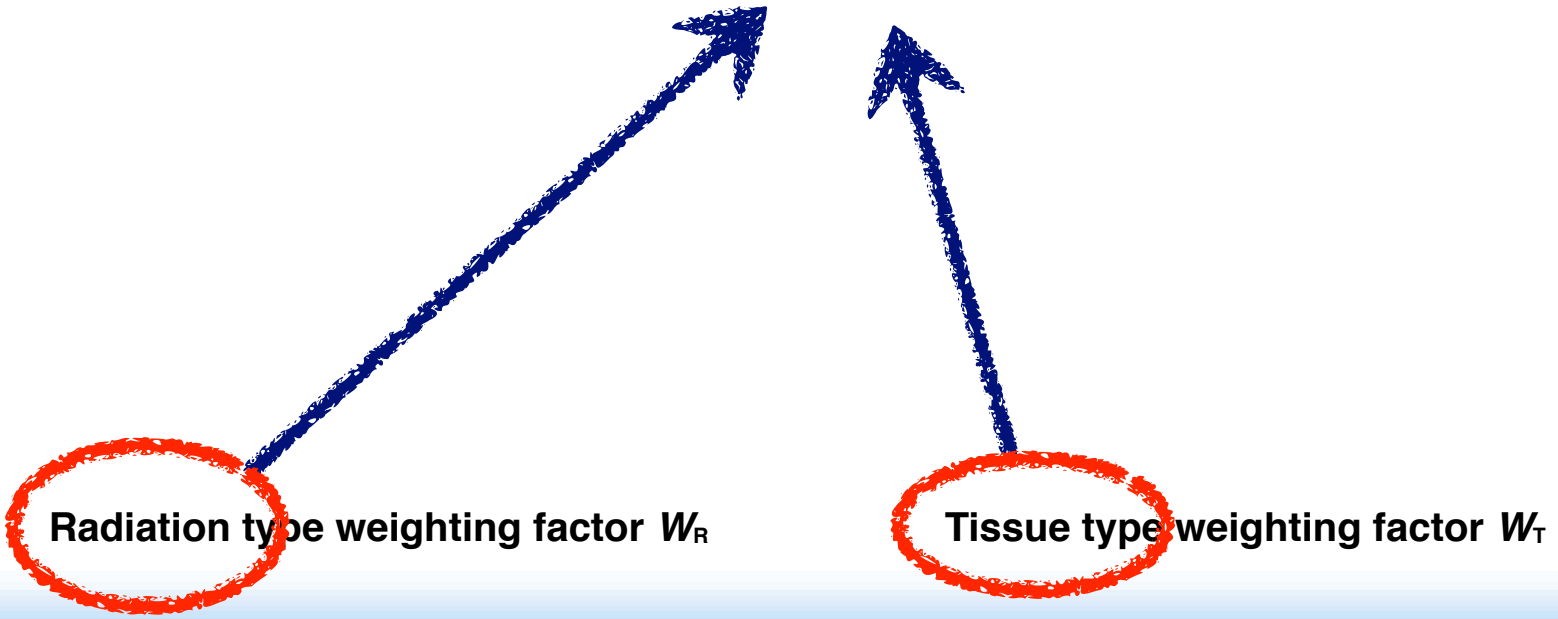
SI unit for radiation effect on tissue
..... Joule/kg

1 Sv represents the equivalent biological effect of the deposit of a joule of radiation energy in a kg of tissue. The equivalence to absorbed dose is denoted by Q.

--> „biological“ quantity
--> **input**

The relationship between Mr. Gray & Ms. Sievert

$$\text{Sievert} = Q \times \text{Gray}$$



Your experiences with Ms. Sievert....

- For **diagnostic cardiac catheterizations**, a median effective dose of **4.6 mSv** was found. **Therapeutic procedures** resulted in a higher median effective dose of **6.0 mSv** because of the prolonged use of fluoroscopy.

- **Patient-Specific Dose and Radiation Risk Estimation in Pediatric Cardiac Catheterization** Klaus Bacher, Evelien Bogaert, Régine Lapere, Daniël De Wolf and Hubert Thierens

Circulation 2005;111;83-89; originally published online Dec 20, 2004; DOI: 10.1161/01.CIR.0000151098.52656.3A

To work with Ms. Sievert in daily practice would be sophisticated and rather accurate in estimating risk of radiation induced damage,
but...

too complicated!!!

Reasonable solution:

--> Mr. Gray domesticated:

Dose area product DAP

Dose area product (DAP)

- **Dose area product** (DAP) is a quantity used in assessing the radiation risk from diagnostic x-ray examinations and interventional procedures. DAP reflects not only the dose within the radiation field but also the area of tissue irradiated.

DAP = Dose x area irradiated

Gy x cm2
mGy x cm2
cGy x cm2

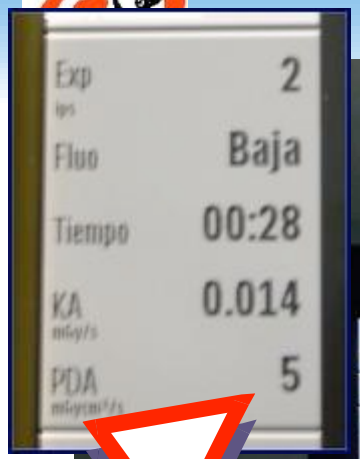
Advantages of DAP:
--> easy to assess (ionizing chamber on collimator)
--> independent of the distance from the source

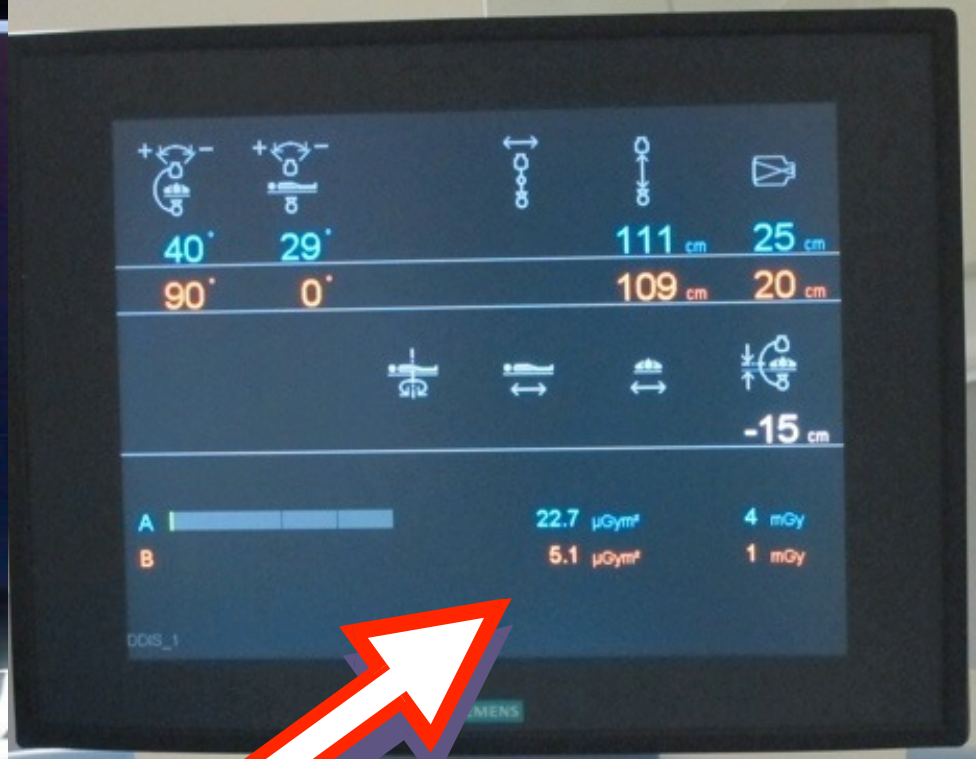
- **Modern X ray systems display dosimetric indications directly on the console in the control room and inside the catheterization laboratory, allowing cardiologists to know the level of radiological risk during the procedure.**

- **Typically Dose Area Product and Cumulative Dose (*) are displayed.**

(*) Cumulative Dose (CD) is the air kerma accumulated for a procedure at a specific point in space relative to the fluoroscopic gantry for a procedure (it does not include tissue backscatter). It can give an indication of the skin dose.

Have you ever paid attention to this?





DAP exposed in your lab

TABLE 2. Demographic Patient Data and Exposure Parameters Used for Diagnostic Catheterizations

	Diagnostic Catheterizations		
	Standard Fluoroscopy (n=15)	Low-Dose Fluoroscopy (n=13)	*P*
Demographic patient data			
Age, y	2.4 (0.1–8.8)	1.3 (0.1–9.2)	0.695
BMI, kg/m^2	14.6 (12.6–21.6)	14.9 (12.6–21.0)	0.945
Exposure parameters			
Peak voltage frontal tube, kV	77.0 (58.3–79.6)	76.6 (71.2–80.3)	0.818
Peak voltage lateral tube, kV	84.9 (59.5–100.0)	85.7 (74.6–102.0)	0.773
Fluoroscopy time, s	294 (30–870)	384 (96–1932)	0.316
Total DAP, cGycm	548 (114–1461)	337 (96–1399)	0.510
Fluoroscopic DAP rate, cGycm /s	0.61 (0.53–0.92)	0.46 (0.22–0.84)	0.042
PA cine runs, n	4.0 (1–9)	3.0 (1–7)	0.293
LAT cine runs, n	3.0 (0–9)	2.0 (0–6)	0.356

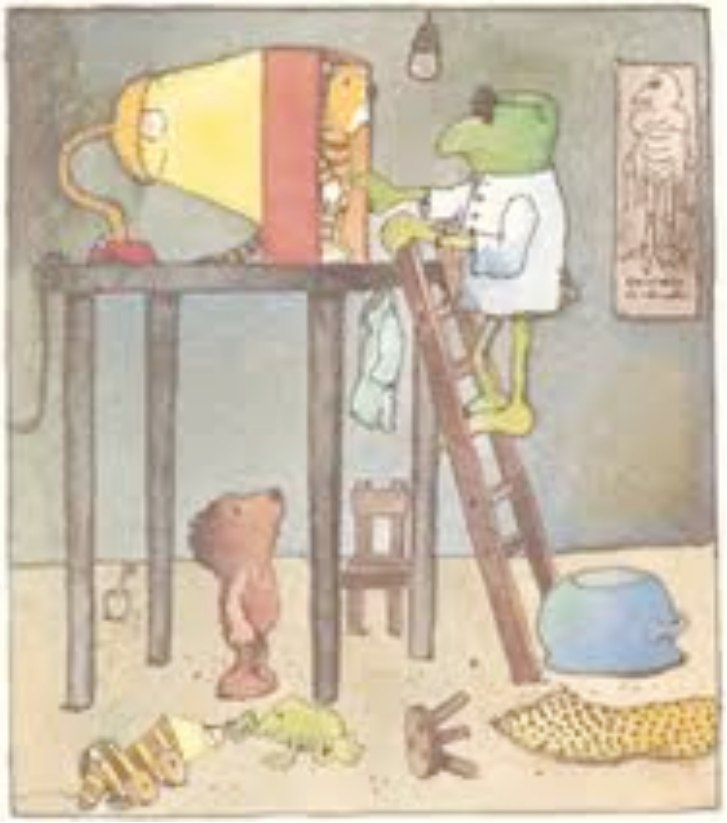
BMI indicates body mass index; PA, postanterior; and LAT, lateral. Values represent the median (range).

TABLE 3. Demographic Patient Data and Exposure Parameters Used for Therapeutic Catheterizations

	Therapeutic Catheterizations		
	Standard Fluoroscopy (n=16)	Low-Dose Fluoroscopy (n=16)	*P*
Demographic patient data			
Age, y	2.0 (0.2–10.0)	2.0 (0.3–7.8)	0.401
BMI, kg/m^2	15.6 (10.1–23.7)	16.3 (13.4–30.1)	0.258
Exposure parameters			
Peak voltage frontal tube, kV	75.0 (56.0–84.8)	79.1 (77.0–91.8)	0.041
Peak voltage lateral tube, kV	83.0 (60.0–96.5)	89.7 (77.0–116)	0.024
Fluoroscopy time, s	401 (182–3612)	300 (42–2466)	0.267
Total DAP, cGycm	472 (282–2044)	272 (41–1800)	0.079
Fluoroscopic DAP rate, cGycm /s	0.71 (0.42–1.11)	0.55 (0.30–0.91)	0.039
PA cine runs, n	3.5 (2–7)	3.0 (2–14)	0.376
LAT cine runs, n	3.5 (0–6)	3.0 (2–13)	0.249

Abbreviations as in Table 2. Values represent the median (range).

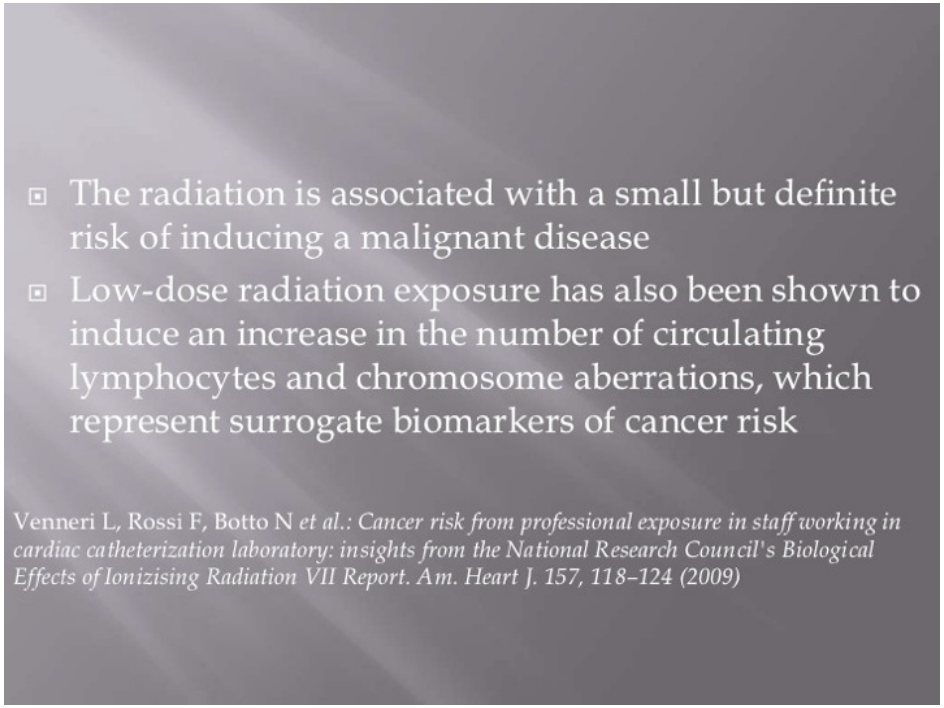
Back to daily life practice...



Why radioprotection ??

For you....!

- Cumulative professional radiological exposure is associated with a **non-negligible Lifetime attributable risk of cancer** for the most exposed contemporary cardiac catheterization laboratory staff. (Am Heart J 2009;157:118-24.)



... and your patient!

- Children are smaller with thinner bones,
- Children's cells reproduce more quickly, so they're more susceptible to aggressive cell growth, tumors, and DNA damage.
- The lens of the eye, thyroid gland, bone marrow and gonads are your child's most radiosensitive organs. Exposing your child's gonads to radiation can produce genetic defects in his offspring due to radiation-induced chromosomal damage.

  Children face a far greater lifetime exposure to electromagnetic radiation, which is significant because the effects are cumulative.

Focus shifting of radioprotection during growth.....

- **Small patient ---> protect him/her!**
  sensitive organs

- **Large patient ---> protect yourself!**
  high scatter radiation

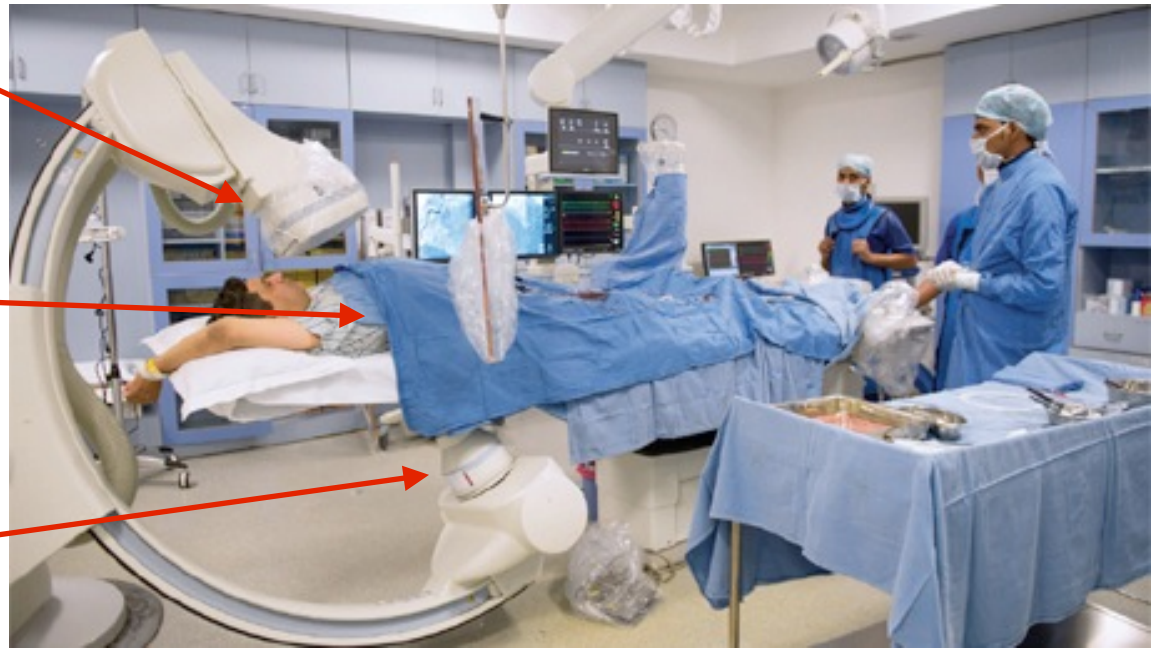
Reality check

- **The occupational radiation hitting you comes from….?**

1.

3.

2.



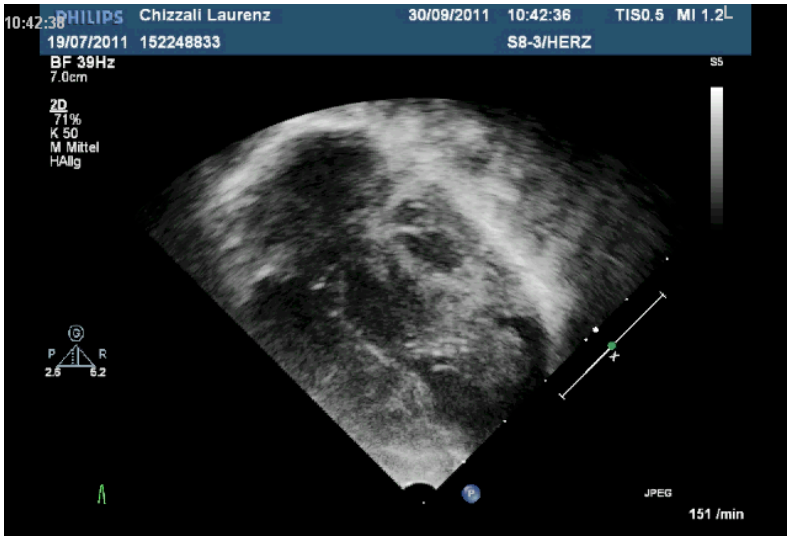
Reality check

you are solely hit
by **scatter radiation**
out of the patient

1. Diagnostic information should be obtained primarily non-invasively.

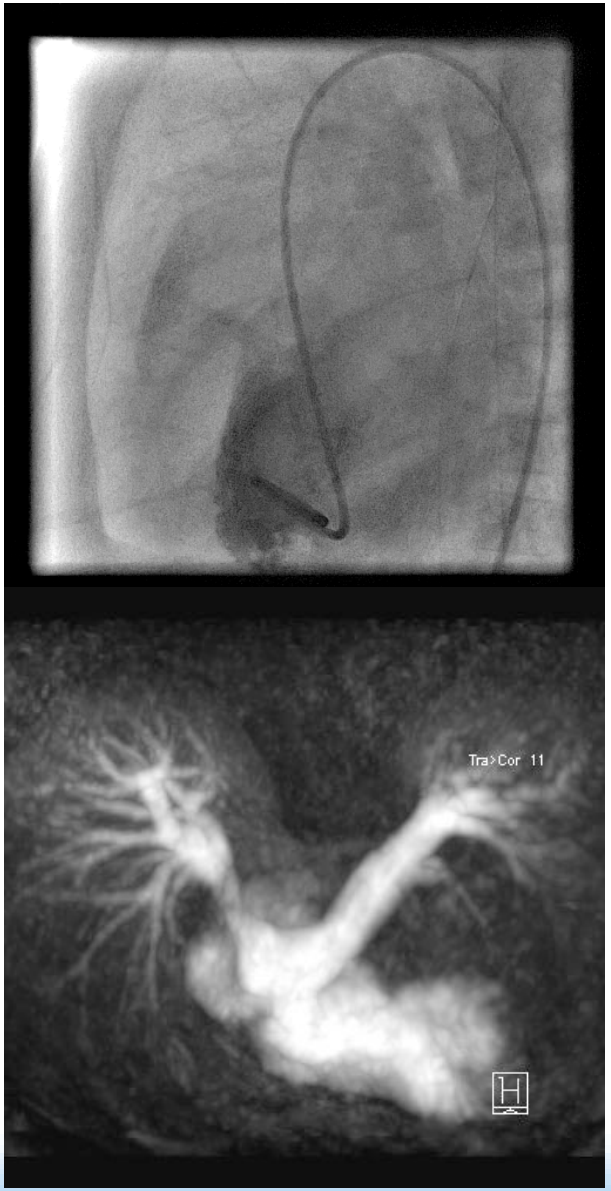
- A thorough history and physical examination
- **complete echocardiogram** in every patient prior to a cardiac catheterization

- *One should avoid obtaining angiograms that provide redundant information already known from non-invasive studies 'just because we're there–*



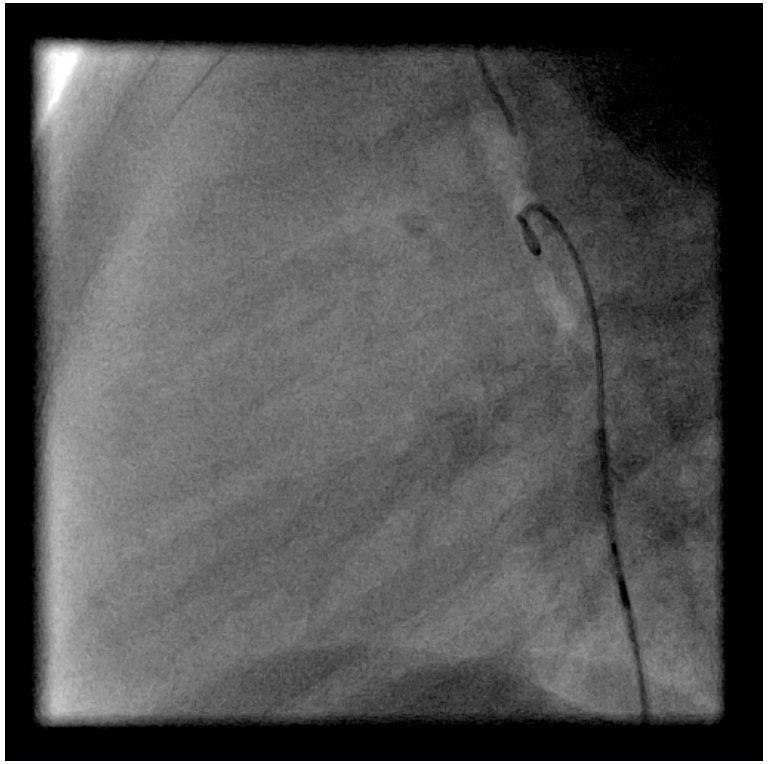
2. Plan the angiographic projections ahead of time.

- **Tables are available that list relatively standard angiographic views** for best profiling some common defects.
- **Careful assessment of the location of a ventricular septal defec**t by echocardiogram aids in predicting which angulated projections should best profile the defect at angiography.
- If an **MR or CT study** has been performed in a patient with branch pulmonary artery stenosis, **reviewing** these studies carefully can help predict how to best image the vessel angiographically with minimal foreshortening and minimal superimposition by surrounding vessels.



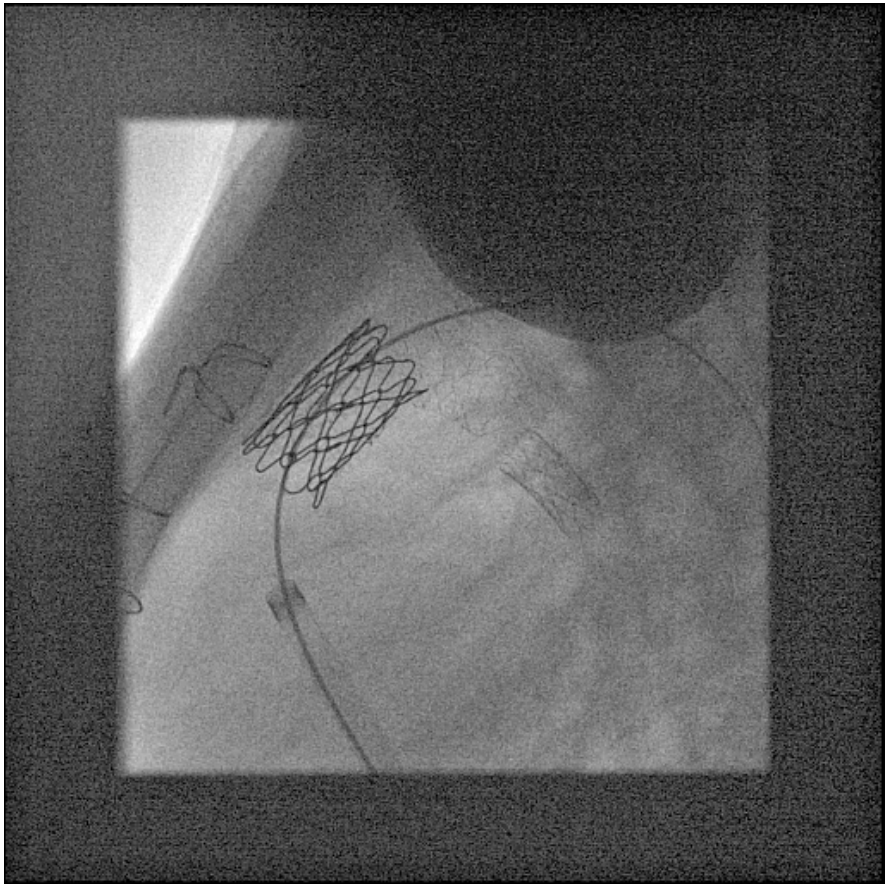
3. Place the patient in the isocenter and straight on the table.

- Having the patient in the isocenter facilitates keeping the heart at the center of the field despite changes in angulated views, without the need for prolonged fluoroscopy to adjust the patient's position with each change in angiographic projection.
- **Certain cardiovascular structures can be reliably found with respect to skeletal and tracheobronchial landmarks** (e.g., the fossa ovalis, the pulmonary arteries, the ductus arteriosus, etc) with minimal trial and error or wasted fluoroscopy.



4. Use the lowest acceptable frame rate during pulsed fluoroscopy and cine angiography.

- Always use **pulsed fluoroscopy**, never continuous fluoroscopy.
- Be prepared to **change the frame rates** frequently during a case depending on the type of structure that is being imaged (e.g., fast-moving vs. slow-moving; venous or arterial).

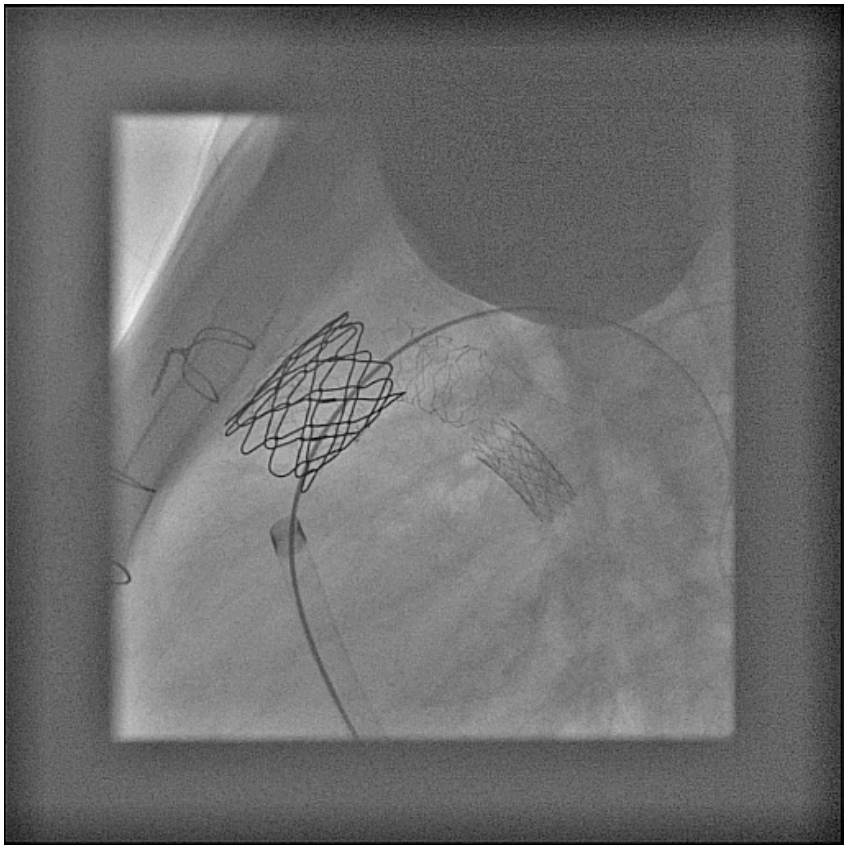


Fluro 3 frames/s

4. Use the lowest acceptable frame rate during pulsed fluoroscopy and cine angiography.

- Always use pulsed fluoroscopy, never continuous fluoroscopy.
- Be prepared to change the frame rates frequently during a case depending on the type of structure that is being imaged (e.g., fast-moving vs. slow-moving; venous or arterial).

- **Newborn 30 (-60) fps**
- **Children 15 (-30) fps**
- **venous 3 (-10) fps**

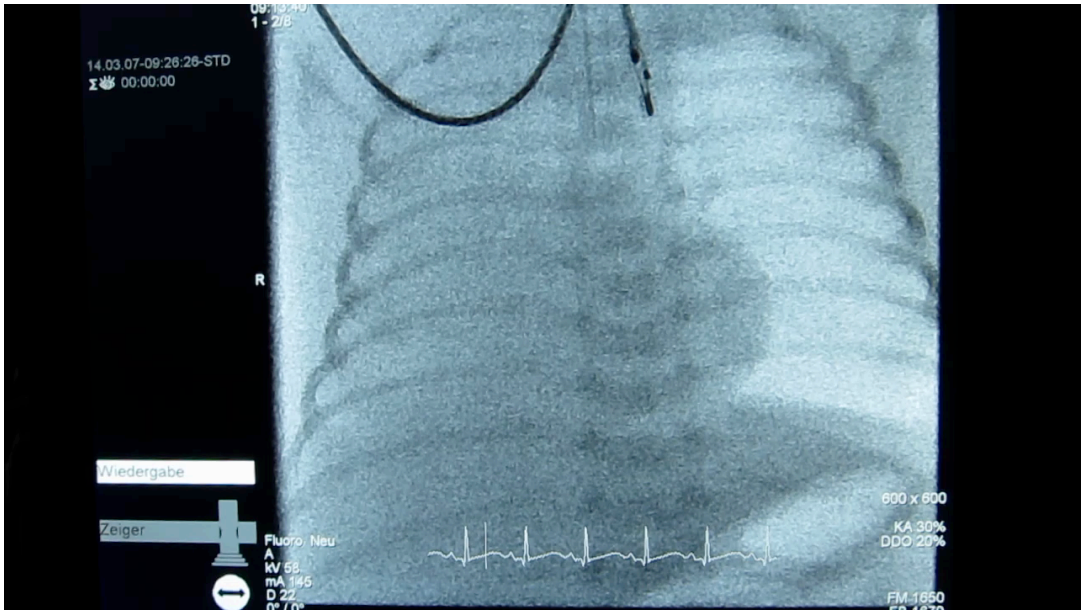


Cine 15 frames/s

5. Do not use fluoroscopy to make changes to the patient/table position or collimators/shields.

Use '**virtual–markers** that enable the positioning of collimators and partial thickness shields without the need for fluoroscopy by indicating their location on the screen.

Even in units that do not have virtual markers, the collimators should still be moved first and checked for position with brief fluoroscopy; they should not be positioned during constant fluoroscopic visualization.



Whats the AEC.....?

- Auto Erotic Console?
- AEPC without P ?

- # Ars Electronica Center?

... we will have Dinner there tomorrow!

Automatic exposure control!!

.... contract with the devil

Sensors between patient and the II measuring the radiation hitting the detector

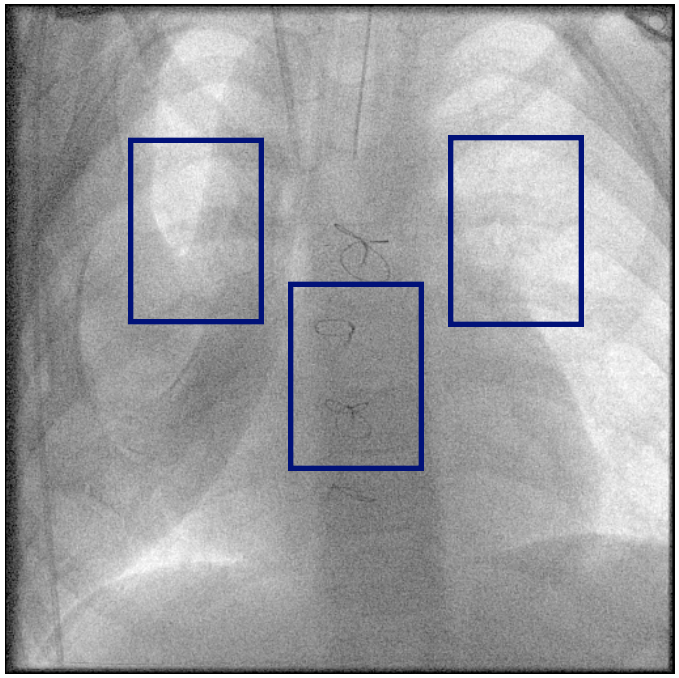
AEC looks for a constant image quality

Therefore every particles (bones, arms, prosthetic valves, clamps, tubes etc.) weaken the received signal resulting in

--> **compensatory increase of emitted radiation energy!**

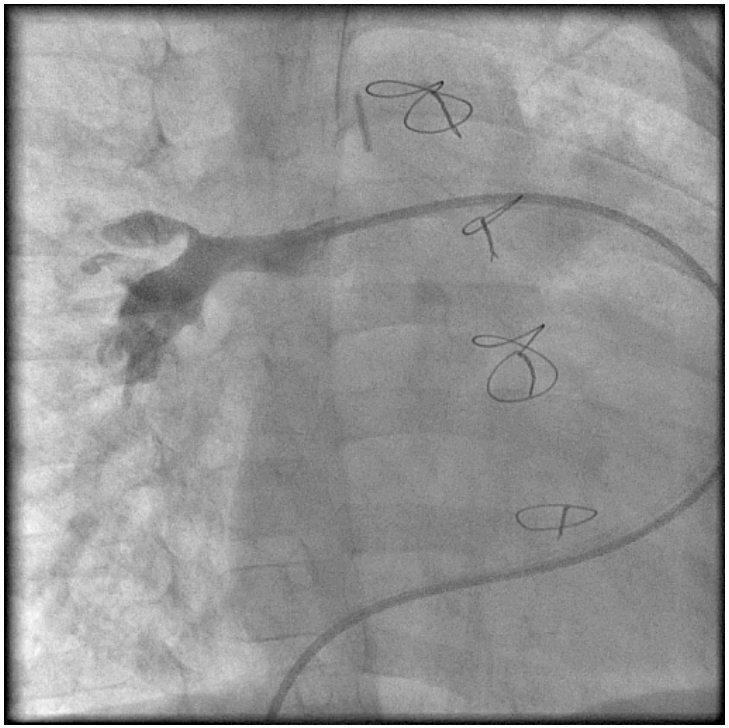
6. Remove unnecessary body parts (or instruments) from the field.

- A typical example of this is leaving the arms in the path of the beam.
- The arms never belong in the field during routine cardiac studies.
- Arms in the field result in an overall increase in radiation exposure to all of the patient's tissues (and to the personnel) because the radioopaque arms drive the AEC to compensate with increased radiation output.
- The same can be said for the operator's hands: there is essentially no reason for the operator's hands to be visible on the screen at any time, and their presence in the path of the beam also drives up the radiation dose to patient and operator. Radioopaque instruments not only obscure the field of interest but also serve to drive up the radiation dose.



7. Use one angiogram to improve on subsequent angiographic projections.

- The first screening angiogram should be carefully scrutinized to determine how to plan subsequent angiograms
- e.g., in the case of a RPA-stenosis that is incompletely profiled, analysis of the lateral angiogram allows one to correct the subsequent angle of the frontal II.
- In this fashion, the second set of angiograms should be able to perfectly profile the lesion, and a third angiogram should virtually never be necessary.

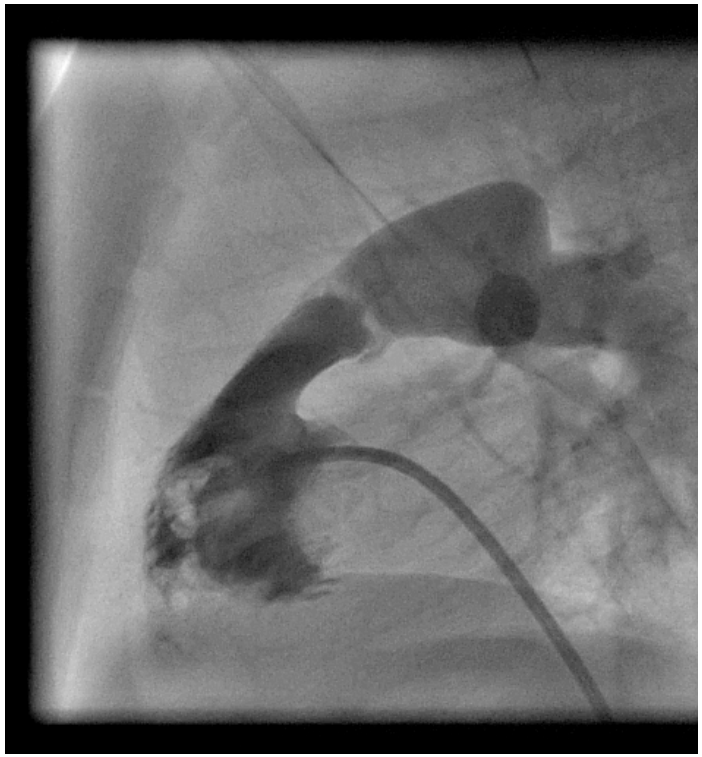


RAO 25° to delineate RPA

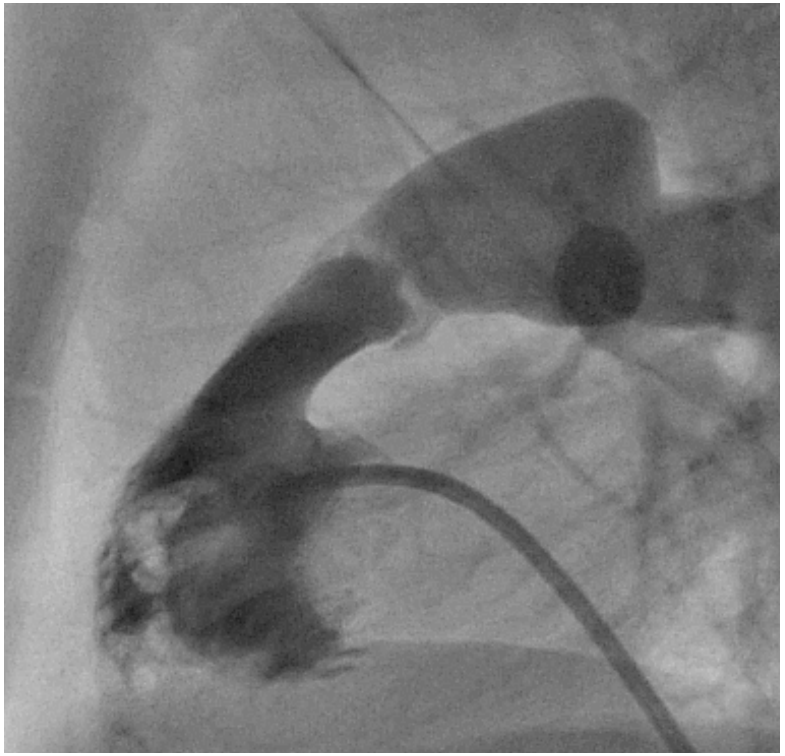
8. Always perform a test injection of a small amount of contrast material using fluoroscopy prior to acquiring an angiogram.

- This approach prevents the wasted angiogram that is taken with the catheter inadvertently wedged deeply in a vessel.
-
- A few extra seconds of fluoroscopy and a tiny amount of contrast material are far less costly to the patient in contrast load and radiation exposure than a wasted angiogram.

What results in more radiation dose?



normal



magnification

9. Use the lowest acceptable magnification mode.

- Electronic magnification is produced by reducing the field-of-view, such that a smaller surface area on the II is being exposed, with the resulting smaller exposed area being magnified to fill the entire visible screen.
- Because a smaller area of the II receives the transmitted radiation, a loss of image brightness occurs, resulting in a compensatory increase in radiation dose.

- **Electronic magnification should be used sparingly, because of the substantial increase in radiation dose it requires.**

- When in magnification mode for an angiogram, do not forget to return to the standard mode for the subsequent parts of the procedure when feasible.

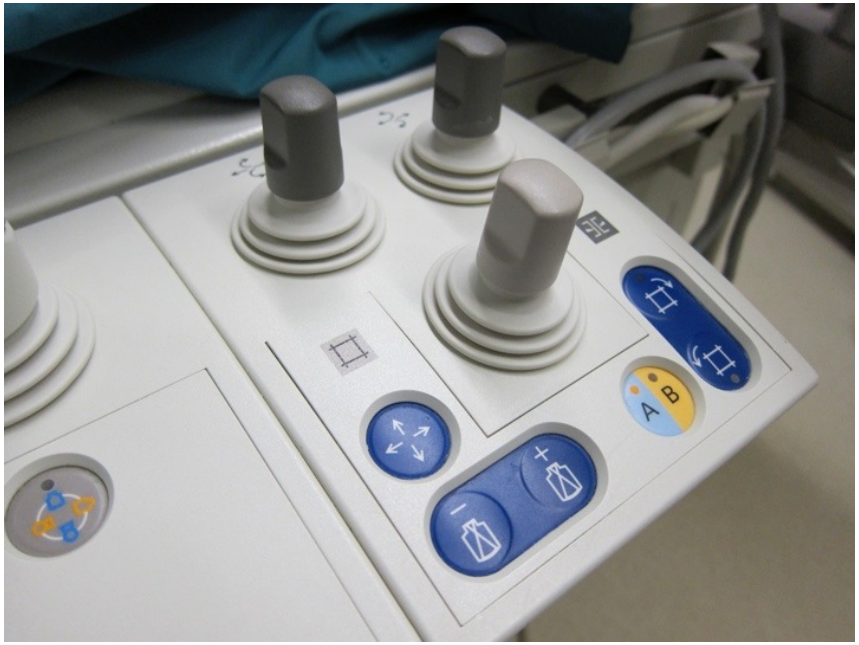
10. Use collimators and partial thickness shields.

- Collimators are extremely beneficial overall in reducing the volume of tissue exposed to the primary beam and in reducing scatter;
- Reducing scatter is, in turn, beneficial for reducing exposure to laboratory personnel and improves image contrast.
- Use of collimators and shields over radiolucent areas, such as the lung fields, improves exposure of the heart within the image.

The collimators should be visible within the field, and studies should not be performed with the collimators wide open.

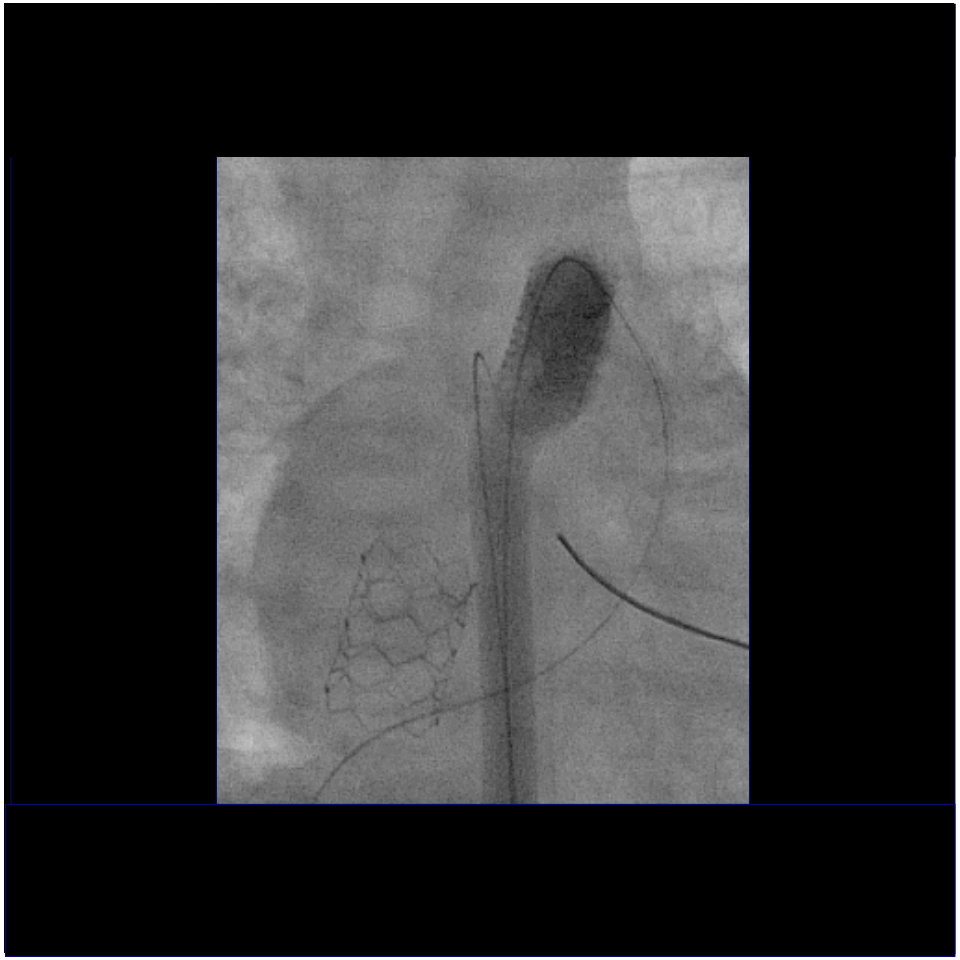
Collimation

- **What are these Joysticks for.....?**



You must play with them in every cath!

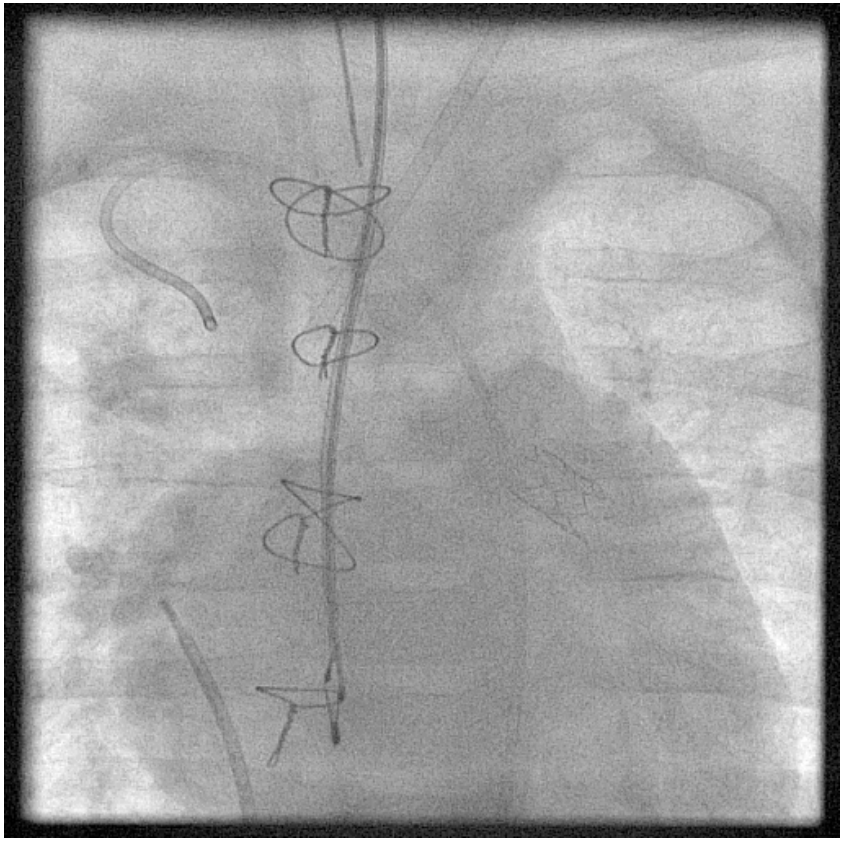
Always think of collimation....



save
> 50 %
of
dose

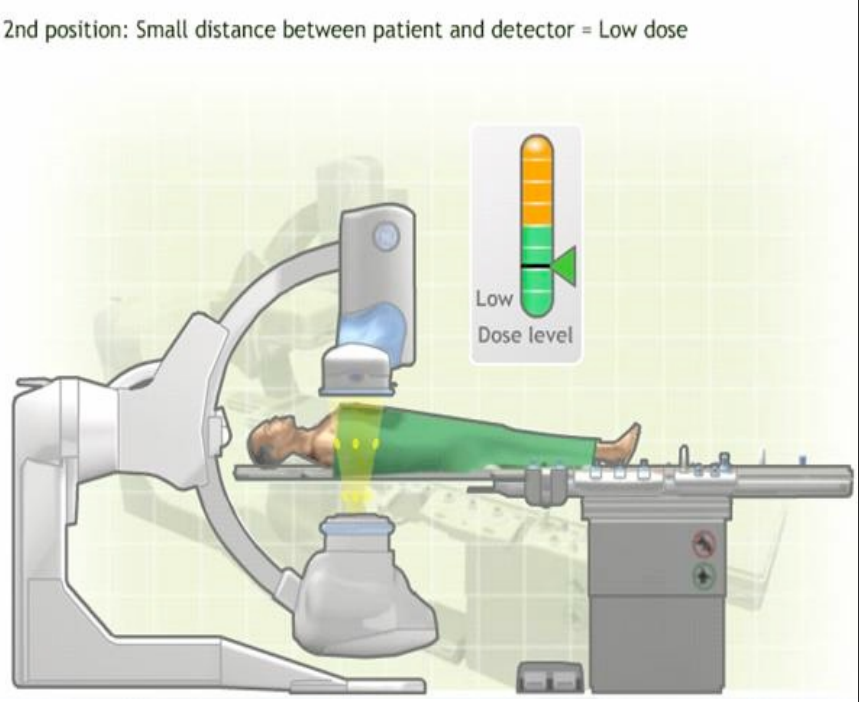
11. Center the region of interest correctly in the field.

- The center of the field has the least amount of image distortion
- Furthermore, bringing the region of interest to the center of the field allows for tighter collimation and less exposure of unnecessary patient tissues to the X-ray beam.
- Last, the AEC sensor is typically at the center of the II, and thus optimal exposure of the structure of interest is best attained if it is brought into the center of the screen.



12. Keep the II as close to the patient as possible (and the X-ray tube as far away as possible).

- The farther the II from the patient the higher the input doses and the greater the scatter to the laboratory personnel.
- A distant II also results in geometric magnification, which introduces geometric blur.
- Keeping the X-ray tube as far away as possible, though recommended in general fluoroscopy, is not usually feasible or practical in pediatric cardiology. Although keeping the X-ray tube far from the patient reduces radiation dose and is a very useful tactic in single plane fluoroscopy (in which case the table height would be set as high as possible), in biplane imaging the heart should be maintained at the isocenter.



13. Use angiographic projections that reduce operator exposure whenever possible.

- RAO projection moves the X-ray tube away from the operator,
- LAO projection moves it closer.

- **The closer the operator to the X-ray tube, the closer he/she is to the surface of the patient that is emanating the highest amount of scatter.**

14. Decrease beam-on time.

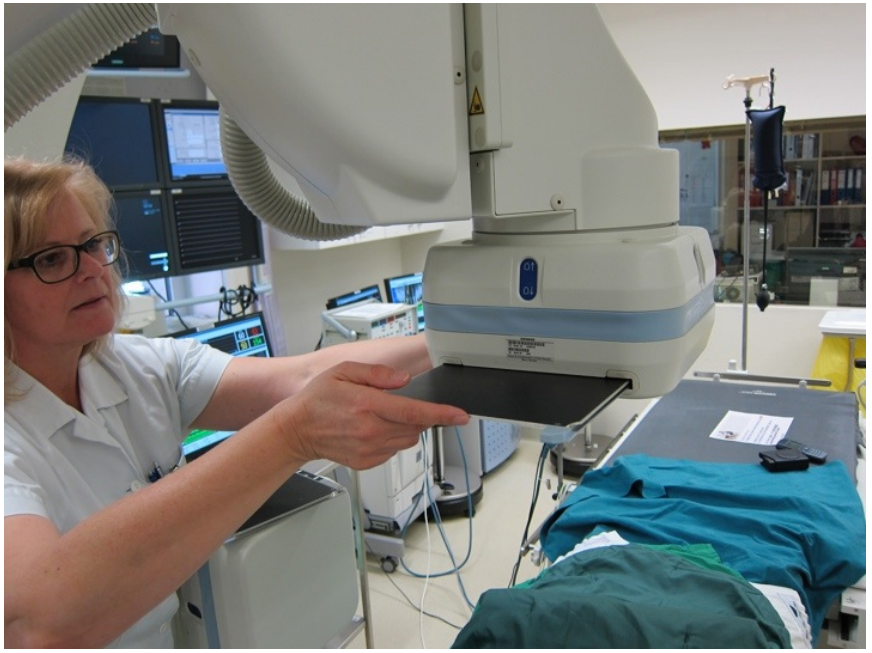
- Most important rules
- Fluoroscopy must not be applied while discussing or contemplating the next maneuver.

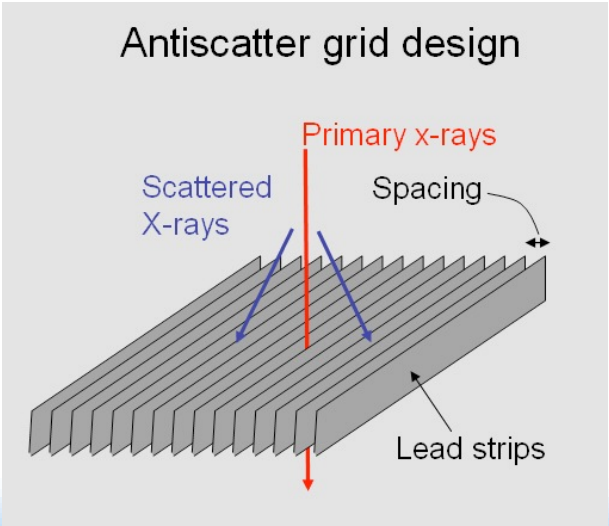
- **If the eye is not on the screen, the foot should not be on the fluoroscopy pedal!**

- Stored images, not live images, should be used for studying the case.
- During catheter exchanges, do not use fluoroscopy continuously, but rather check the wire position periodically with quick brief bursts of fluoroscopy.

15. Remove anti-scatter grids when catheterizin small patients (< 30kg).

- Useful in adult patients where a big amount of scatter radiation emanated by the patient itself is filtered in order to have a better image
- **Small children only produce a small dose of scatter-radiation** which does not influence the image quality.





16. Use X-ray stand position memory.

1. Store useful projections in memory for rapidly returning to them when necessary without the need for fluoroscopy to verify position.

17. Use roadmap and overlay features.

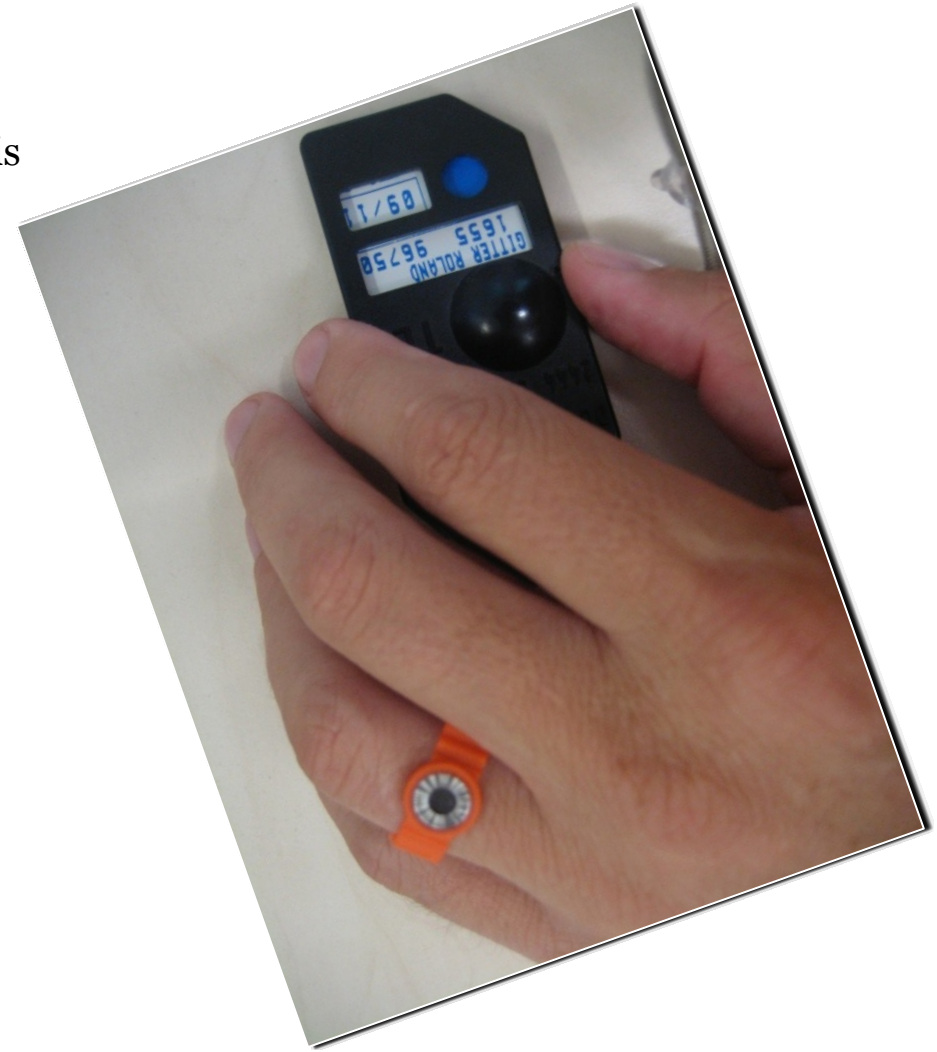
- Use your good quality angiogram either
- in a side-by-side roadmap, or
- superimposed on a live fluoroscopy image that can be faded in or out of view as needed.
- These features allow vessels of interest to be found with minimal trial and error.
- They can assist with confirmation of wire position without the need for additional contrast injection.

18. Be familiar with your own laboratory equipment and features.

- Work with your radiation safety officer,
- a radiation physicist,
- and the manufacturer to regularly test and maintain the equipment in optimal working condition.
- Aging equipment will result in degradation of image quality and a need for higher radiation doses. Repair and/or replace aging equipment as required.

19. Ensure protection of laboratory personnel.

- Before initiating fluoroscopy at the start of a procedure, ensure that everyone in the room is shielded.
- Ask everyone to move away from the patient during cine angiography. Make use of the inverse square law.
- Operators must always make use of hanging acrylic shields. Other personnel should stand behind mobile shields when feasible.



19. Ensure protection of laboratory personnel.

leadglass eyewear with side shields reduce radiation exposure to the eyes of the operator by approximately 90% (Thorntonetal.,2010).

•protects lens and furthermore protect your eyes agains splattering blood or fluid

not that ugly nowadays - so even Eva wears them !!

Choose correct aprons

Back is completely unprotected

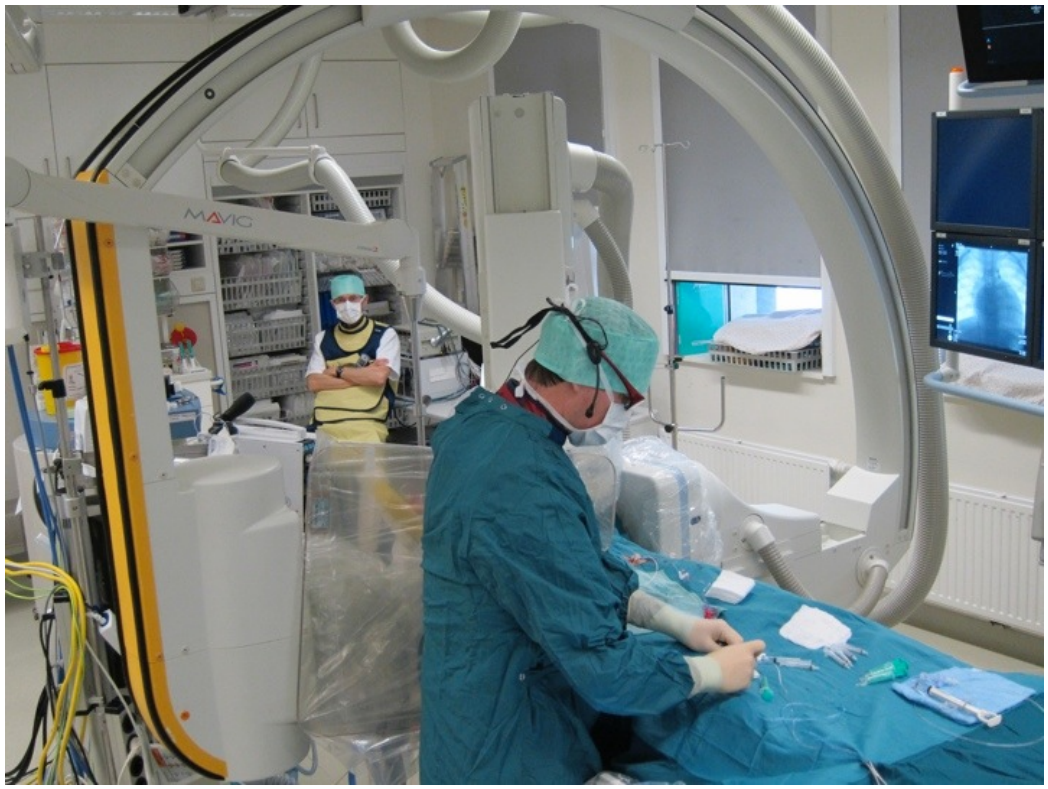
Choose correct aprons....

Personnel moving around must wear wrap-around aprons to be fully protected

Dont forget the anaesthetist….

too close position receiving much of the scatter radiation from patient

Dont forget the anaesthetist....



if ever possible - and at least during cine acquisition - keep distance to the anaestetist

20. Create a culture that strives toward radiation awareness and safety.

- **Data collection**
  - **procedures, DAP, fluoro time**
- **Data analysis**
  - **reliability of data**
- **Discussion & processes review**
  - **collimators/filters use, FOV, projections**
- **Implementation of changes**
  - **more precise data collection, collimators/filters use, small FOV whenever possible, avoiding LAO projections**
- **Data verification**

- Regularly discuss issues of radiation safety with nurses, technicians, and trainees. Include regular didactic seminars within a structured training program.

Dose comparison between bad and optimal

• 3 pulses/s vs. 30/s	10
• oblique projections	4
• beam-on time experienced. vs. unexper.	2
• too big distance patient to II	4
• Zoom	2
• Kollimation	2
• --> total difference (product of all):	1280 x

Optimization means …

- **To avoid acquiring more images than necessary:**
  - **Take care of the fluoroscopy time.**
  - **Take care of the number of series.**
  - **Take care of the number of frames per series.**
- **To avoid acquiring images with more quality (and more dose) than necessary:**
  - **It could be possible to accept sometimes some noisy images in fluoroscopy and also in cine acquisitions.**

Thank you very much...

...see you there tomorrow