

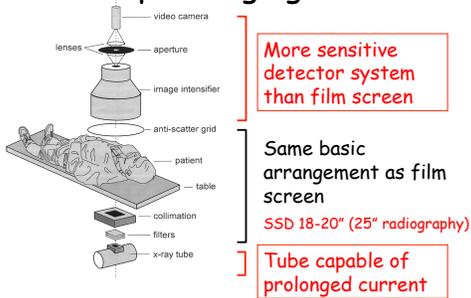
Fluoroscopy

David Dubowitz MD PhD

Fluoroscopy

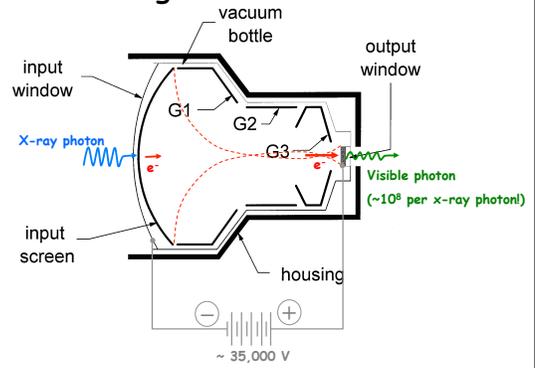
- Real-time radiographic imaging (30fps)
- Used for positioning (not necessarily recorded):
 - Positioning catheters/biopsies/needles (e.g. angio)
 - tracking contrast media (HSG, ERCP, sinogram)
 - positioning prior to radiography/spot/cine (e.g. Ba)
- Long exposure
 - need to keep radiation dose low
 - Need VERY sensitive detector (200-600x film-screen)
- Most systems are digital (or soon will be) - but physics of conventional fluoroscopy with image intensifier still needed for ABR

Fluoroscopic imaging chain

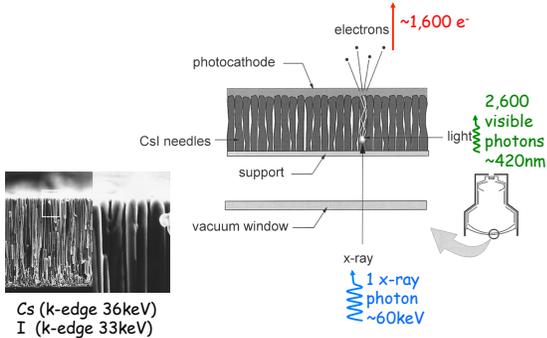


Large spot 1-1.2mm (0.3-0.6mm for radiography),
 Low current 1-3mA (200-800mA for radiography)
 Long exposure ~10 mins (<1sec radiography).

Image intensifier



Energy conversion at input phosphor



Energy conversion at output phosphor

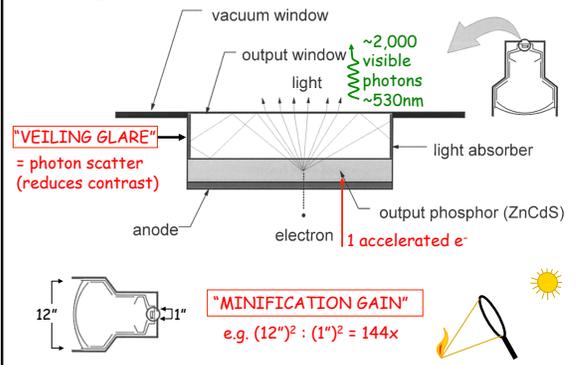
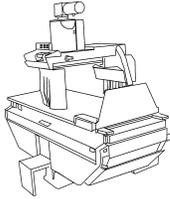
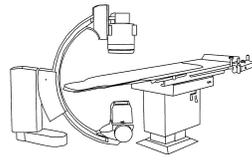


Image Intensifiers

- 23-, 30-, 35, 40-cm diameter (9,12,14,16")
 - Large - GI/GU
 - Small - Cardiac/arthroscopy



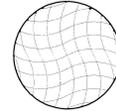
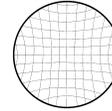
R/F System



Angiography System

Image Intensifiers

- Distortion:
 - Pincushion distortion
 - "S-distortion" (spiral)



Different path-length of electron beam
 - Longer path at periphery (more distortion)

Spiral warp due to electron path in stray magnetic field

- Vignetting:
 Image is brighter at the center of Image Intensifier screen

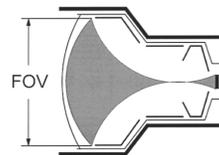
Practical tip: Position tissue of interest at center of fluoro screen
 - less distortion, more brightness, better contrast

Image Intensifiers

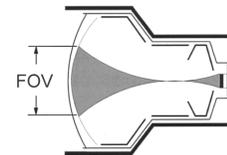
- Conversion Factor (= "gain")
 - light out (Cd/m²) : X-rays in (mR/sec) [Cd s / mR m²]
 - Typically 100-200
- Brightness
 - Electronic gain (~50x) × Minification gain
 (Minification \propto input:output area \sim (input FOV)² in inches)

Image Intensifiers

- Magnification
 - Reduce input FOV - magnifies & reduces pincushion
 - But...reduces brightness gain



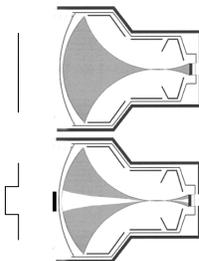
Normal Operation



Magnification Mode

Image Intensifiers

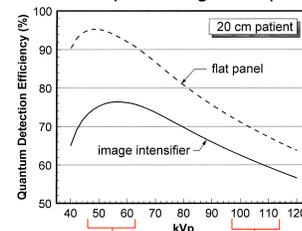
- Contrast ratio
 - indirect measure of veiling glare



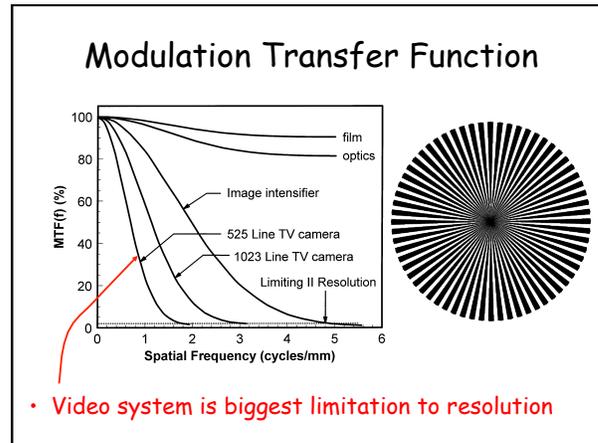
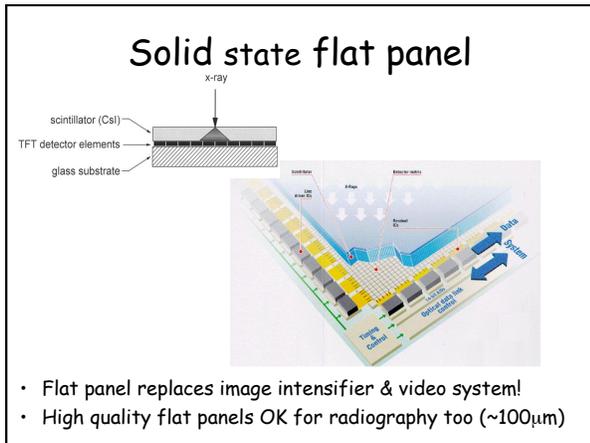
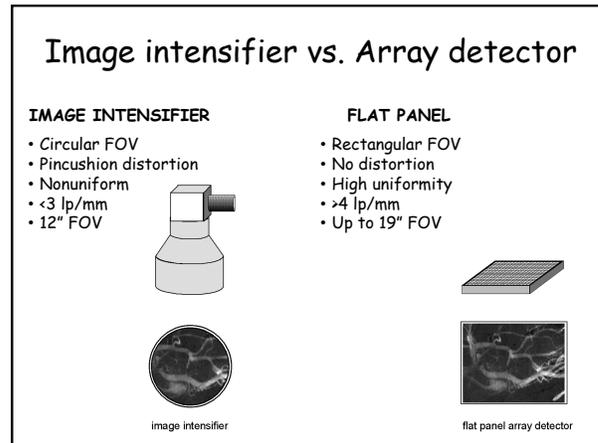
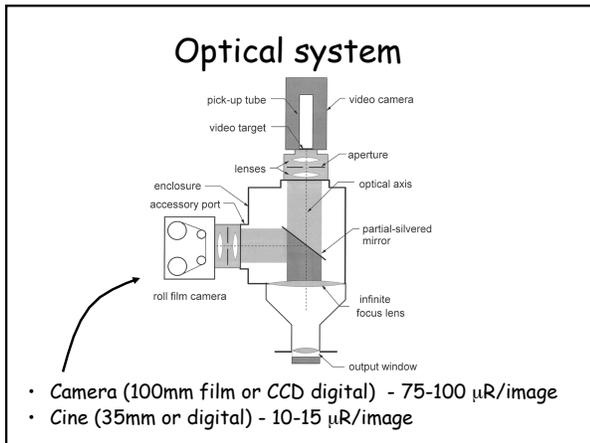
Contrast ratio = A/B
 (Typically 15-30)

Image Intensifiers

- Quantum Detection Efficiency
 - 1.5mm Al in II reduces QDE compared with flat panel
 - QDE max at 60kVp - but higher kVp reduces dose



kVp for max efficiency 60 120 kVp for lower dose



Dose reduction

- Balance of dose vs. noise
 - Higher dose = lower noise (+ better detectability) and v.v

1 mR 0.1 mR 0.01 mR

- Balance of dose vs. mortality/morbidity
- Reducing patient dose reduces YOUR dose

Dose Metrics for Fluoroscopy

- **Cumulative Air Kerma (mGy)**
 - Kinetic energy released in matter (air)
 - Analogous to "Exposure in mR"
 - Deterministic effects (skin)
- **Kerma Area Product (also DAP)**
 - Unit: $\text{mGy}\cdot\text{cm}^2$ (also $\text{mGy}\cdot\text{m}^2$)
 - AK x Area
 - Proportional to Stochastic Risk
- **Cumulative Fluoro time (min)**
 - Very poor indicator of dose
 - May be only available on units pre-2006
- Peak skin dose*
- Skin dose maps*

*Desired but not readily available

Exp	0	fps
Tilt	0	
SID	120	
FD	13.0	
-ray disabled		
Live display		
Exp	30	fps
Fluo	Normal	
Time	19:29	min
AK	1484.90	mGy
DAP	184522	$\text{mGy}\cdot\text{cm}^2$
58:00		

Mike Andre's 10 Pearls of Dose Reduction

Some recommendations

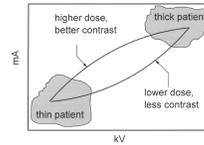
1. Use Automatic Brightness Control (ABC)
2. Minimize use of magnification modes
3. Always collimate to region of interest
4. Minimize use of spot fluorographs (spot films, DSA, cine), use and record LIH
5. Spread dose to skin by changing tube angle and position
6. Always use lowest appropriate fluoro pulse rate and frame rate for dynamic sequences
7. Use system geometry to reduce patient dose and personnel scatter radiation exposure
8. Use personnel and patient protective devices correctly
9. Record dose report in PACS and chart, periodically review AK values
10. Observe notification and sentinel event levels

Most measures that reduce patient dose also reduce Staff dose

1. Automatic Brightness Control

- Adjust radiation exposure (mA, kV, pulse width, pulse height) to keep output phosphor brightness constant.
- Higher mA → higher dose
- Higher kVp → lower dose since ABC reduces mA
- Small body parts: 70 kVp
- Large body parts: 100-120 kVp
- Iodine contrast: >66 kVp (Iodine K-edge)
- Can choose "high dose" or "low dose" algorithms:

Automatic Brightness Control (ABC) Curves

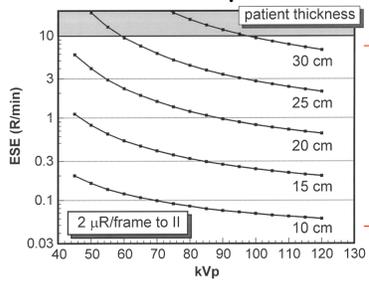


Program Mode:

Different calibration curves for different body types - optimizes contrast vs. dose

Needs weekly QA (potential for unknowingly using high dose)

Entrance Skin Exposure vs Energy

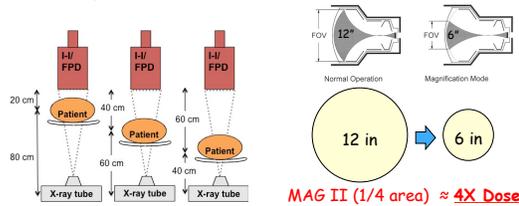


Note:
ESE is lower at high kVp for all body types

- Max patient dose = 10 R/min
- (Auto Brightness control = 5 R/min)

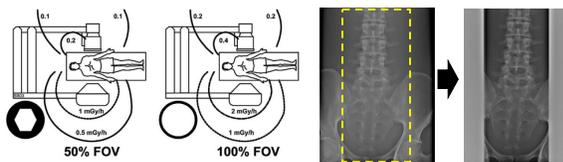
2. Minimize use of Magnification Modes

- Avoid geometric magnification, electronic MAG
- Dose rate depends on the area of FOV
- Dose rate proportional (mag factor)²
- Use digital zoom instead



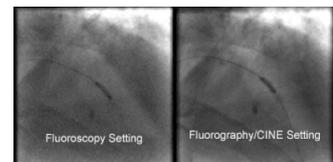
3. Collimate to region of interest

- Adjust collimator without fluoroscopy turned on
- Improves image contrast by reducing scatter
- Use spacer cones if applicable
- Collimating reduces dose, improves image contrast



4. Minimize use of spot fluorographs (digital spot films, DSA, cine)

- Spot images and series require higher doses than fluoroscopic viewing
- Use "Tap Fluoro" and Last-Image-Hold (LIH)
- Save LIH in lieu of spot where possible

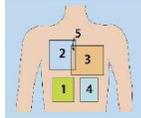


Fluoroscopy
1 nGy

Fluorography
10-60 nGy

5. Spread dose to skin by changing tube angle and position

- Often recommended when Cumulative AK Alert Level is reached (2000 mGy) but do so carefully
- Tricky issue: angulation can increase dose if patient thickness is increased
- Most prevalent skin injury factor is long exposure to single site
- 83% of injuries with beam in steeply angled orientation
- Avoid lateral projections

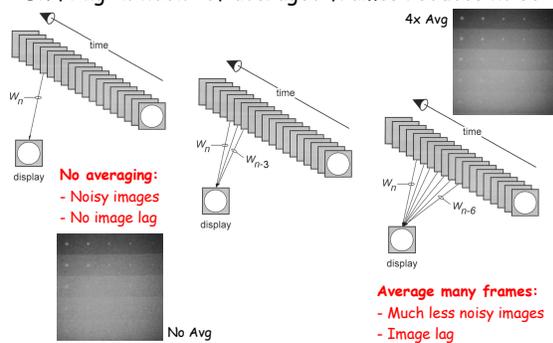


6. Lowest appropriate fluoro frame rate

- Minimize beam-on time
- Use fluoro only to observe motion or positioning
- Use intermittent "tap fluoro" method
- Most IR procedures: 2-7.5 fps
- Cardiology/EP: 7.5-15 fps
- Arthrograms or needle guidance: 1-2 fps
- Use shorter pulse lengths to reduce blur (2-20 msec)

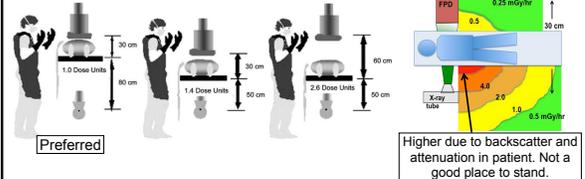
Cine mode noise

- Shifting "window" of averaged frames reduces noise



7. Use system geometry to reduce pt dose and personnel scatter radiation exposure

- Keep detector close to patient, keep tube away
- Scatter radiation originates in patient
- Operator always stands by detector, not by x-ray tube
- Use under-table tube systems whenever possible
 - Operator not shielded from scatter with over-table units
 - Drapes not feasible with over-table units



8. Use personnel and patient protective devices correctly



9. Record+Review Dose Report in PACS and Chart

- Record following data (ACR Guidelines)
 - Operator (MD)
 - Air Kerma
 - Kerma Area Product
 - Fluoro Time
 - Skin location for higher dose component



10. Observe notification and sentinel event levels

- First Notification Level 3000 mGy AK
- Announce AK to team every 1000 mGy thereafter
- For cumulative AK >3000 mGy
 - Instruct patient on self-exam for erythema for 2-3 weeks
 - If reddening does not fade after 4 weeks or is painful, patient should return for examination
- For cumulative AK >5000 mGy
 - Schedule Dermatology consult for patient 4-8 weeks after procedure
 - Avoid skin punch biopsies (may lead to non-healing ulcer)
- Report AK >5000 mGy to Radiation Safety Office
 - Review case with RSO and/or Medical Physicist
 - Estimate skin dose to a single port
- The Joint Commission Sentinel Event
 - 15,000 mGy skin dose to a single field
 - Report to Radiation Safety and Patient Safety Manager
 - Initiate Sentinel Event review

Mean effective doses and DAP values from contrast procedures involving fluoroscopy

Radiography / Fluoroscopy procedures	Mean Effective Dose (mSv)	Mean DAP (mGy cm ²)	Equivalent number of PA chest radiographs (each 0.02 mSv)
Orthopaedic pinning (hip)	0.7		35
Pelvimetry	0.8		40
Micturating Cystourethrogram (MCU)	1.2	6400	60
Hysterosalpingogram (HSG)	1.2	4000	60
Discography	1.3		65
Barium Swallow	1.5		75
Fistulogram	1.7	6400	85
Cystography	1.8	1000	90
Myelography	2.46	12,300	123
Barium meal	2.6		130
Barium meal follow through	3		150
Sinography	4.2	16,000	210
Barium enema	7.2	28,000	360
Coronary angiography	2-15 (12.7)	49,000	635

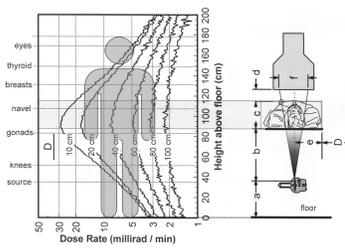


IAEA Radiation Protection of Patients, rpop.iaea.org

Patient Dose reduction

- ABC
- Avoid High Dose mode
 - Usually only needed for obese patients
- High kVp, Filter beam, Collimate beam
- Short bursts (with last frame image hold)
- Reduce Frame rate
 - Typically 30 fps (<7.5 fps may work while positioning)
- Frame averaging
- Pulsed fluoroscopy
 - E.g. 10ms exposure rather than 33ms (for 30 fps)

Dose Rate to radiologist



- Fluoroscopy is a significant source of occupational exposure
- Everything that reduces patient dose also reduces your dose!
- 1m away at 90° you get 0.1% of the patient dose
- Remember $1/r^2$!

End

Sample Q's

2002 G52:

The output of a fluoroscopic unit is 10 mR/min at 50 cm. The output at 75 cm :

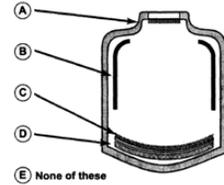
- A. 15.0
- B. 7.5
- C. 6.6
- D. 5.0
- E. 4.4

Sample Q's

2002 D31-35:

Match the following components to the figure of the image intensifier (II) tube:

- D31. Focusing electrode
- D32. Input screen
- D33. Photocathode
- D34. Output screen
- D35. Vacuum getter



Sample Q's

2002 D36:

The fluoroscopic operating factors displayed on a monitor are 120 kVp and 10mA. Which of the following is true?

- A. The skin entrance dose is unusually low.
- B. The five-minute timer is broken.
- C. The skin entrance dose is extremely high.
- D. The display must be wrong.
- E. The anti-scatter grid is not in the beam.

Sample Q's

2002 D37:

The maximum vertical resolution in lp/mm for a 23-cm input diameter image intensifier coupled to a 1024 line TV system is

- A. 0.8
- B. 1.5
- C. 2.2
- D. 3.1
- E. 4.0

Sample Q's

2002 D38:

The major differences between fluoroscopy and standard radiography include all of the following except:

- A. Focal spot size.
- B. Spatial resolution.
- C. Tube current.
- D. Tube potential.
- E. Source-to-skin distance.

Sample Q's

2002 D90:

Interventional radiology procedures require significant fluoroscopy, and can deliver patient entrance doses of up to mGy.

- A. 2
- B. 20
- C. 200
- D. 2,000
- E. 20,000

Sample Q's

2002 D94:

The principal source of radiation exposure to personnel during fluoroscopy is:

- A. Leakage from the x-ray tube housing.
- B. Radiation scattered from the patient.
- C. Radiation scattered from the image intensifier.
- D. Electrons leaking from the image intensifier.
- E. Radiation scattered from the walls and floor.

Answers

Sample Q's

2002 G52:E

By the inverse square law: $I_{75} = I_{50} \times (50 / 75)^2 = 4.4 \text{ mR/min}$.

Sample Q's

2002 D31-35

- D31. B
- D32. D
- D33. C
- D34. A
- D35. E

Sample Q's

2002 D36:C

As the fluoroscopic beam is positioned over thick or more dense areas of a patient, the penetration of x-rays decreases. The factors of 120 kVp and 10 mA indicate that the image intensifier is not receiving enough transmitted radiation through the patient. At such high technique factors the patient's skin entrance exposure is extremely high. A broken timer will not affect the technique, and a missing grid would tend to decrease the factors.

Sample Q's

2002 D37:B

Of the 1024 lines in a standard TV only about 980 lines are used to actually trace out the image. It takes two lines to make a line pair, so there are $980/2 = 490$ line pairs. However, small objects are generally not perfectly aligned between the TV lines, so the effective resolution is obtained by multiplying by the Kell factor, which takes into account the random positioning of small objects in the TV field. The Kell factor is generally about 0.7, so the effective resolution is about $490 \times 0.7 = 343$ line pairs. For a 23-cm (230-mm) input, the resolution would be $343/230 = 1.5 \text{ lp/mm}$.

Sample Q's

2002 D38:D

The focal spots for fluoroscopy are typically 0.3 or 0.6 mm; those for standard radiography are usually 1.0 to 1.2 mm. The spatial resolution for fluoroscopy is usually limited by the TV system to 1.8 to 2.5 lp/mm, while radiography has resolutions of 4 to 8 lp/mm. The tube current for fluoroscopy is usually 1 to 3 mA in order to limit anode heating for the long exposure times of 3 to 10 minutes; because of the short exposure times (less than 1 second) of radiography, tube currents of 200 to 800 mA can be used. Tube potentials are the same for both procedures. SSDs in fluoroscopy are usually 18 to 20 inches, while the SSDs for radiographs are typically about 25 inches (except for chest radiographs).

Sample Q's

2002 D90:D

1 to 2 hours of fluoroscopy could deliver 100 to 300 rad, or 1000 to 3000 mGy.

Sample Q's

2002 D94:B