Fluoroscopy 2

Fluoroscopic Imaging Modes and Image Quality

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Variable Imaging Modes

- Fluoroscopy
- Fluorography
  - Dynamic Record
  - Digital Spot
  - DSA
- Rotational Angio/3D/CT

Fluoroscopic Modes of Operation

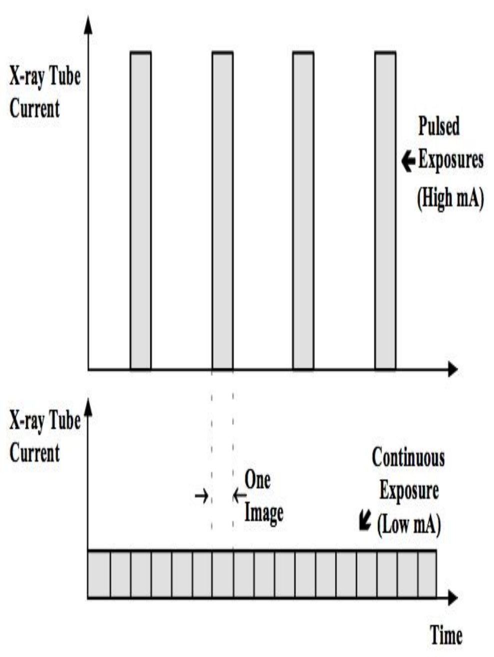
- Continuous fluoroscopy

  a) Typically using 0.5 to 6 mA
  b) Displays the image at 30 FPS
  c) Each fluoroscopic frame is displayed for 33 ms(1/30 s).
  d) Blurring of rapidly moving objects

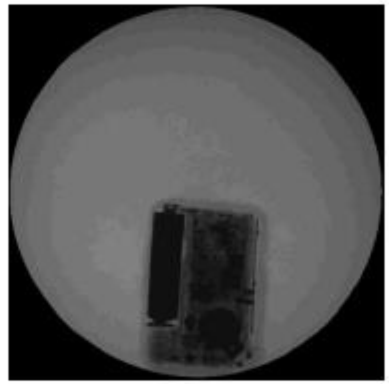
Fluoroscopic Modes of Operation

- Variable Frame Rate Pulsed Fluoroscopy
  a) The pulsed fluoroscopy system can generate up to 30 pulses/s.
  b) Each pulse can be very short about 3 to 10 ms instead of 33 ms.
  c) Pulsed fluoroscopy offers better image quality at the same average dose rate in fluoroscopic procedures where object motion is high(e.g. positioning catheters in high pulsatile vessels).
  d) Pulsed fluoroscopy at selectable frame rates (typically 30, 15, 10, 7.5 and 3.75 FPS) allows the fluoroscopist to reduce dose to the patient.
  e) For example, in a carotid angiography procedure, initially guiding the catheter from the femoral artery access to the aortic arch might allow the use of 7.5 FPS –reducing the radiation dose

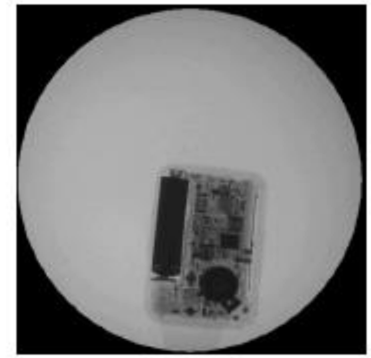
Continuous vs. Pulsed Fluoroscopy



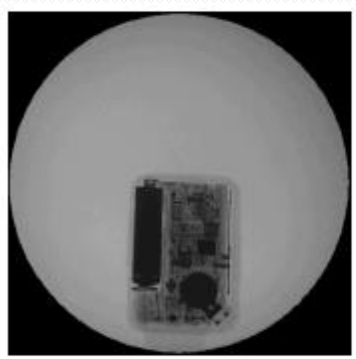
Comparison of continuous fluoroscopy at pulse width of 33 ms, and with pulsed fluoroscopy at pulse width of 3-10 ms



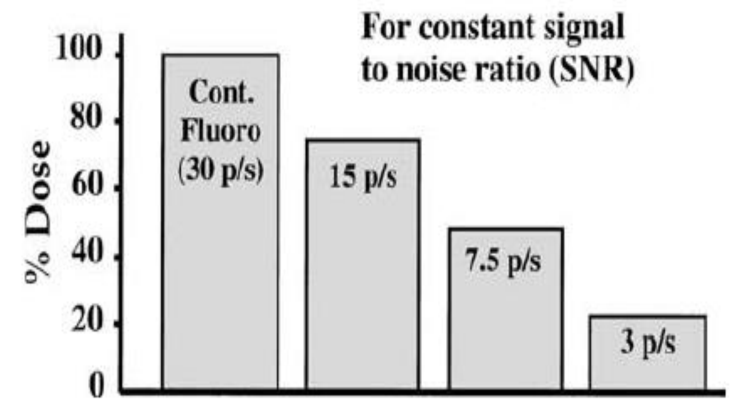
Continuous fluoroscopy



15 pps

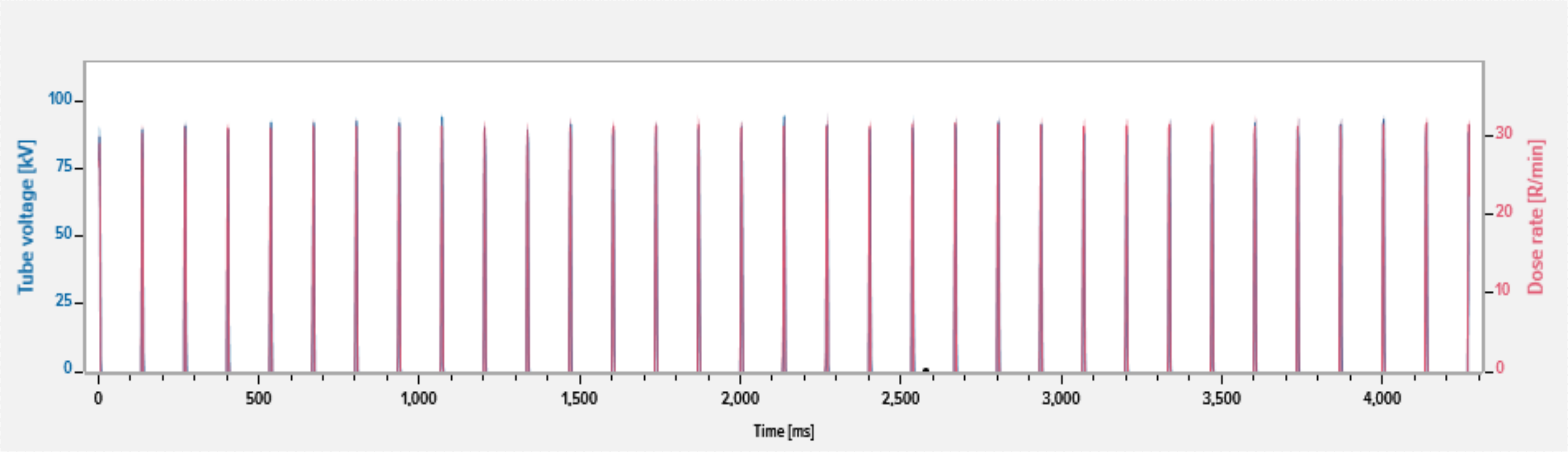


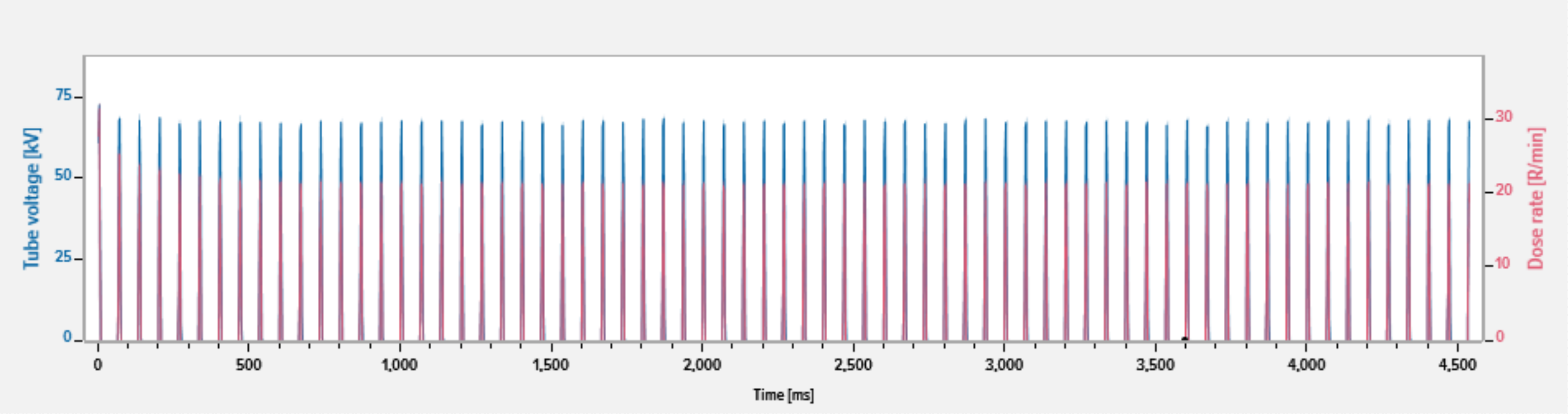
3 pps



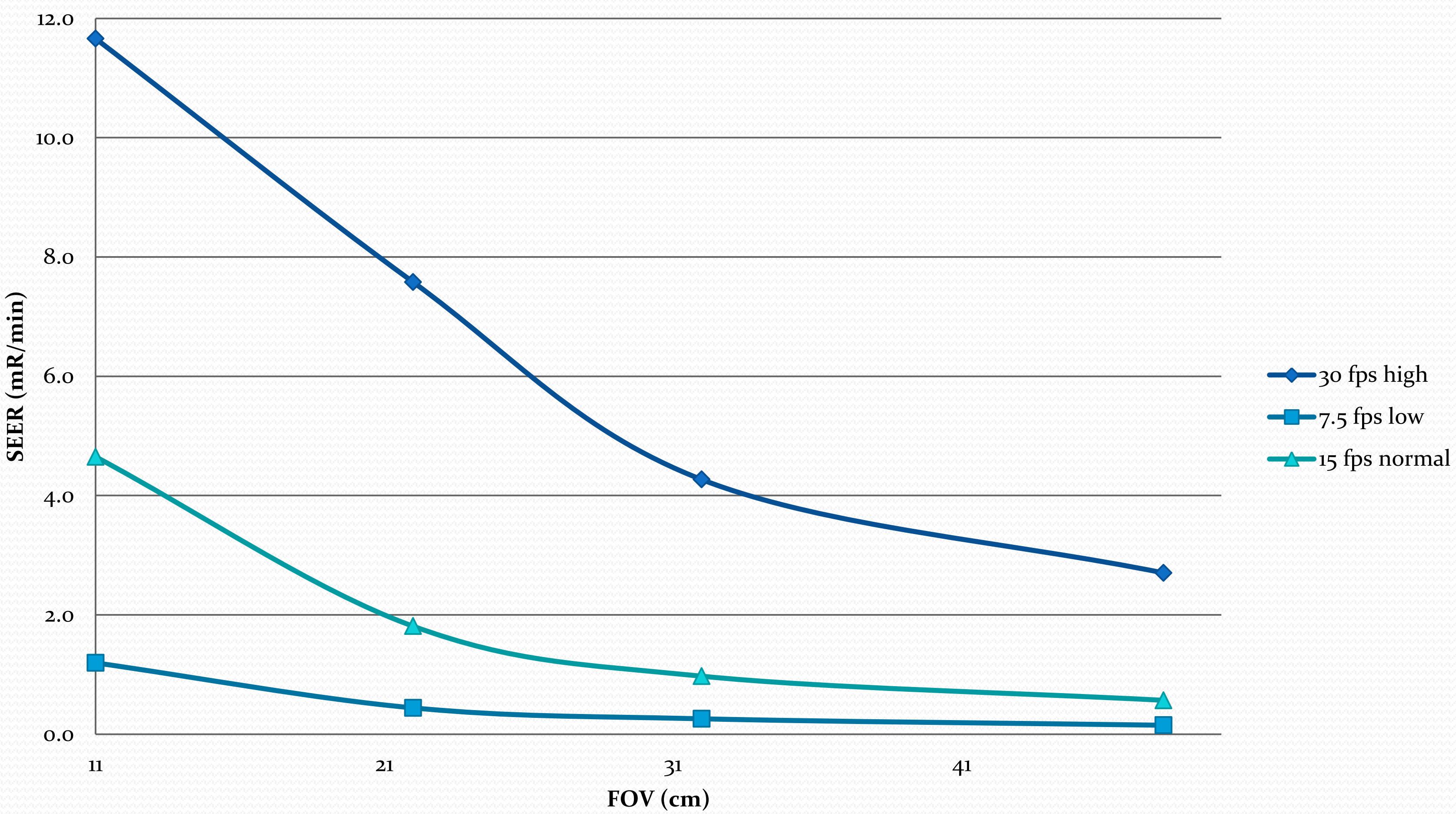
Effect of pulsed fluoroscopy on entrance skin dose. For example, by switching from continuous fluoroscopy (*Cont Fluoro) mode to 15 pulses per second,* dose savings of nearly 22% are achieved

Waveforms for 7.5 fps and 15fps pulsed fluoroscopy at BWH Cath Lab 10

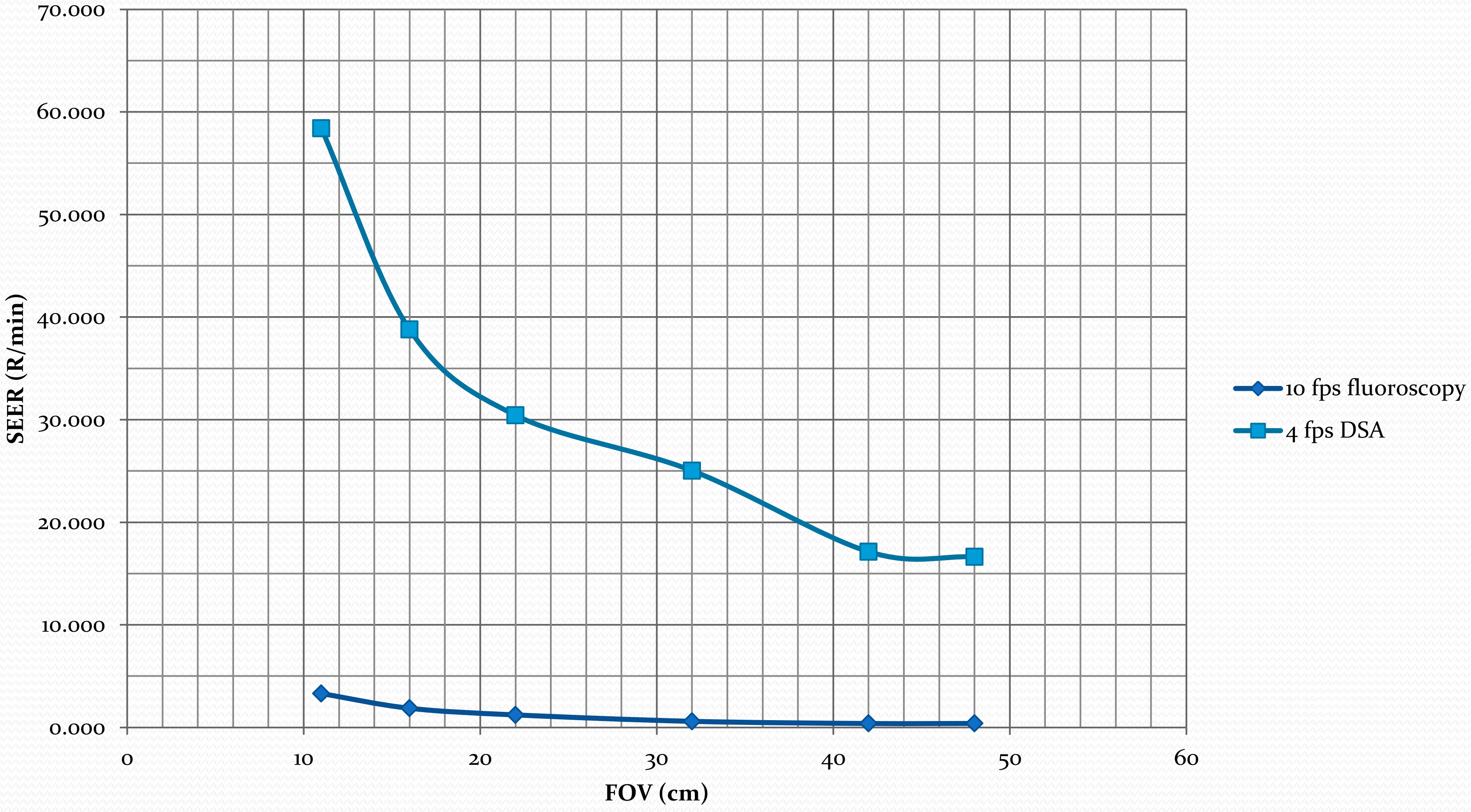




Skin Entrance Exposure Rates with Variable frame rate pulsed fluoroscopy at BWH NIR room 1



Skin Entrance Exposure Rates with Fluoroscopy and DSA at BWH NIR room 1



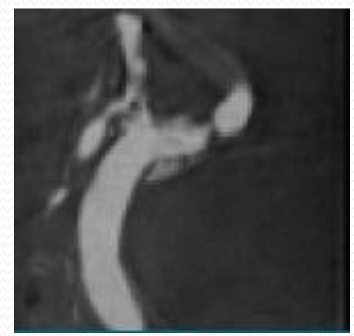
Rotational Angio/3D/CT on Flat Panel Angiography Systems

Vascular, bone and soft tissue 3D imaging in the intervention suite

Rotational
Acquisition

Automatic
3D Recon

3D Images



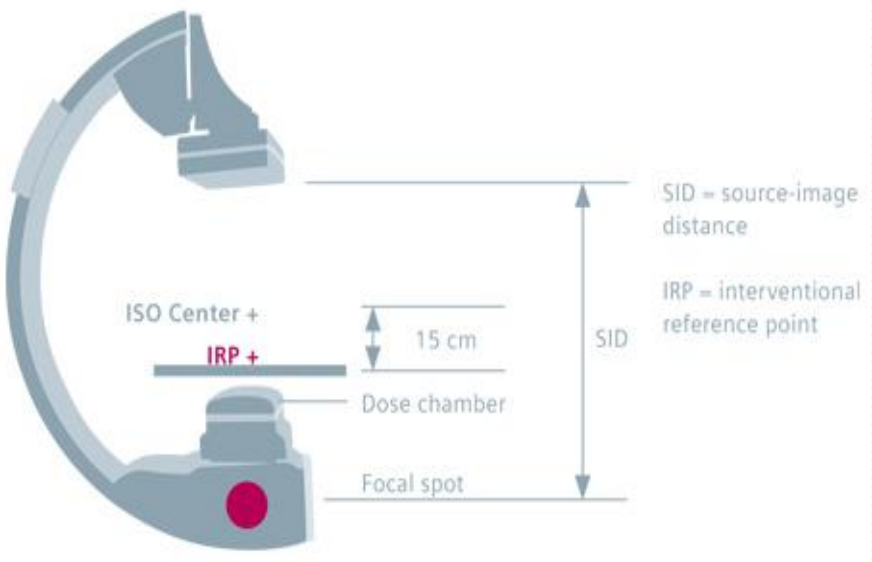
Cross-sections

3D Display
In Several Formats

Radiation Dose metrics in Fluoroscopy

- DAP (Gycm^2)
- AKR (mGy/min)
- Accumulated Air Kerma (mGy)

- Using SID of 100 cm and an SSD of 70 cm, at the entrance side of the patient, half of the dose is delivered in the first 3-5 cm of tissue, which is why skin exposure is of concern.
- With high kVp and the use of copper filters, the mid- abdomen dose is approximately 17 % of the entrance skin dose and only 3% of the primary radiation dose exits the patient to reach the image receptor



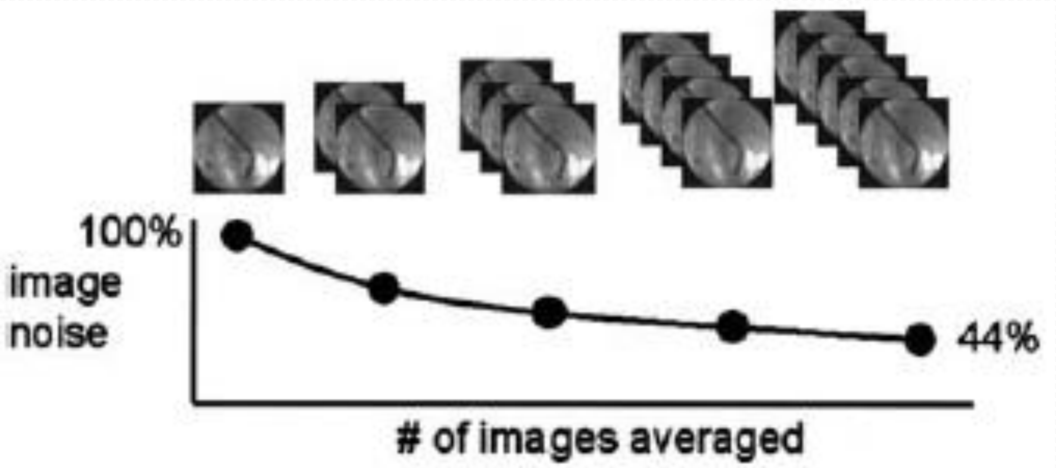
Schematic C-arm, detector, tube, table; location of dose and dose rate measurement.

Image Processing in Fluoroscopy

- Frame Averaging (or FNR Fluoro Noise Reduction)
- Last-image hold and last- series hold
- Digital subtraction angiography (DSA)
- Road mapping
- Cone beam CT
- DRM: Dynamic Range Management

Frame Averaging

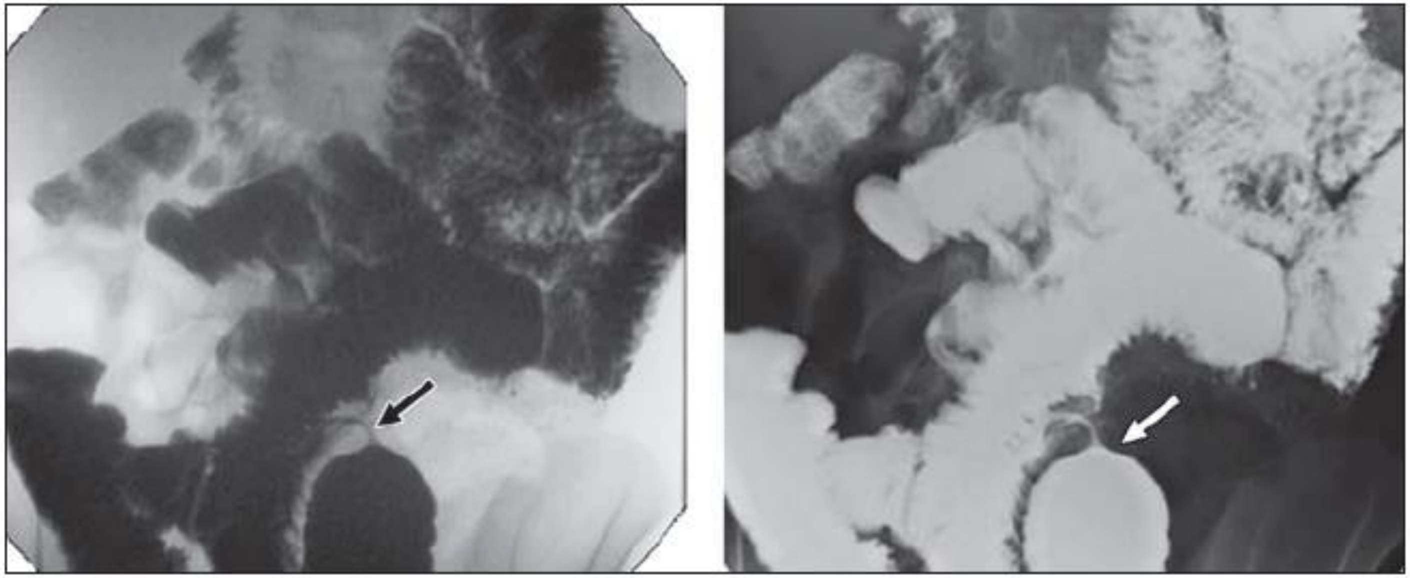
- Temporal frame averaging is used to decrease displayed image noise.
- Averaging more frames together decreases image noise further.
- Frame averaging may work well for static images, but the increased image lag may be unacceptable for imaging dynamic processes.



Averaging five frames together may decrease image noise by up to 44%. As more frames are averaged together, display lag (persistence of displayed objects that have shifted position in the field of view) will increase.

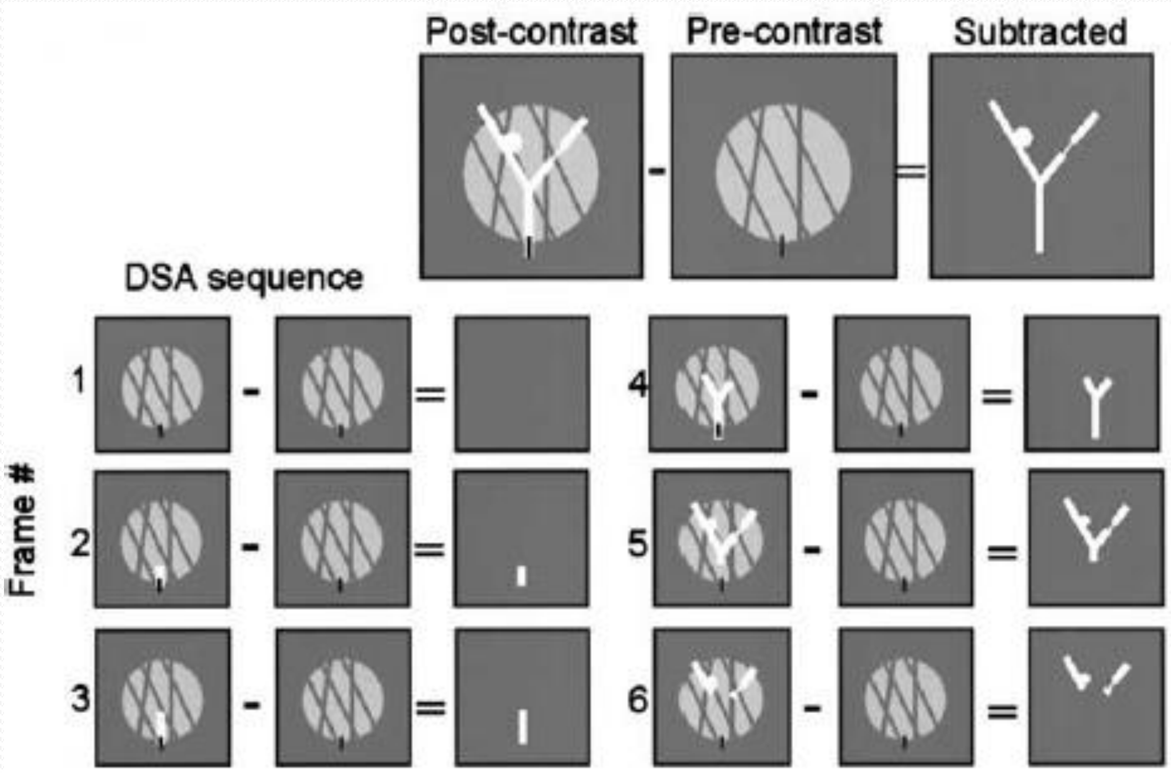
Last Image Hold

a. During the fluoroscopy , when you step off the pedal, the last few frames of fluoroscopy information are averaged together, yielding an image called the last image hold.
b. Due to frame averaging, this image is substantially better than the live fluoroscopy image.
c. Use of this feature will dramatically decrease the ionizing radiation exposure to the patient and medical imaging staff.



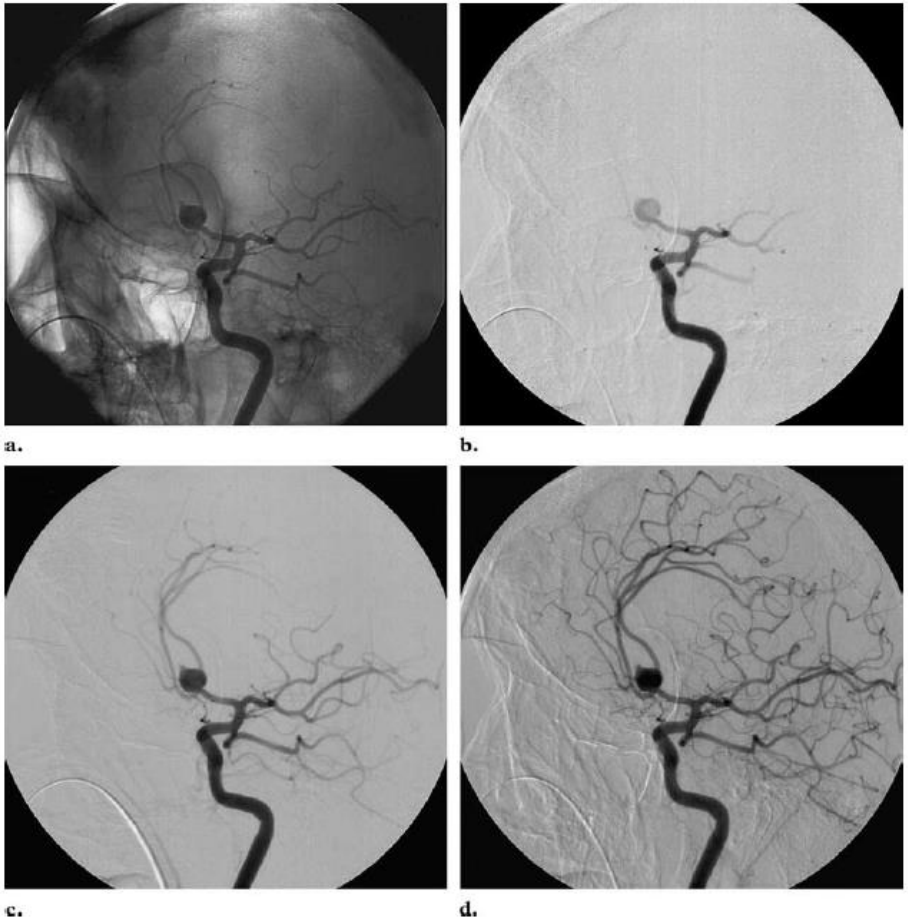
Fluoro grab image (left) and radiographic exposure (right) of similar field of view in patient with bowel stricture (arrows). Note overall similar findings, but with improved mucosal detail in radiographic exposure.

Digital Subtraction Angiography



DSA. A precontrast mask image (which shows a distracting background structure and the tip of a catheter) is subtracted from a postcontrast image obtained at the same location (which shows contrast material–filled vessels). The result is an image of only the contrast material–filled vessels. During the actual imaging sequence, the subtraction process may begin slightly prior to contrast material injection, with each frame capturing a different phase of the injection. The sequence of subtracted frames can then be reviewed in cine mode or as still frames. The unsubtracted original digital fluoroscopic images are generally not reviewed

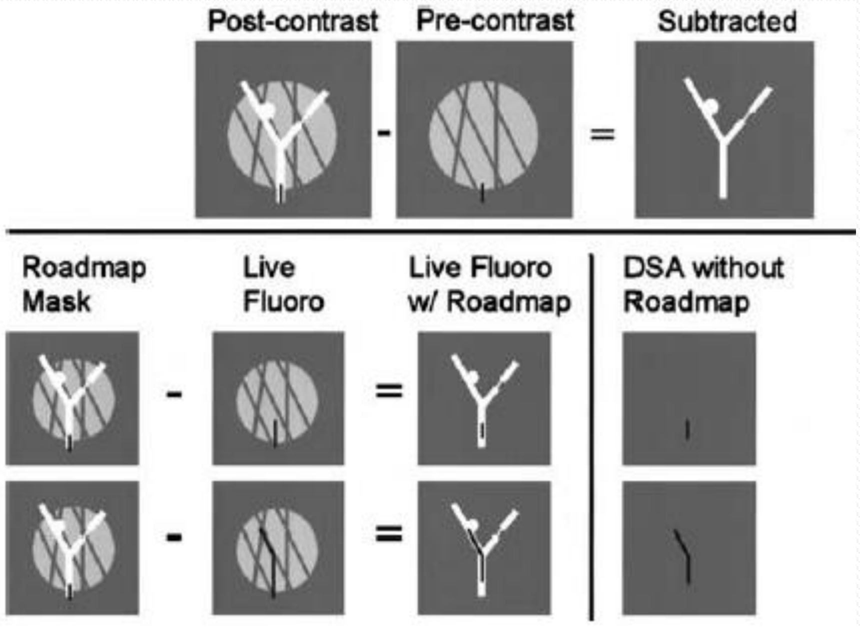
Digital Subtraction Angiography

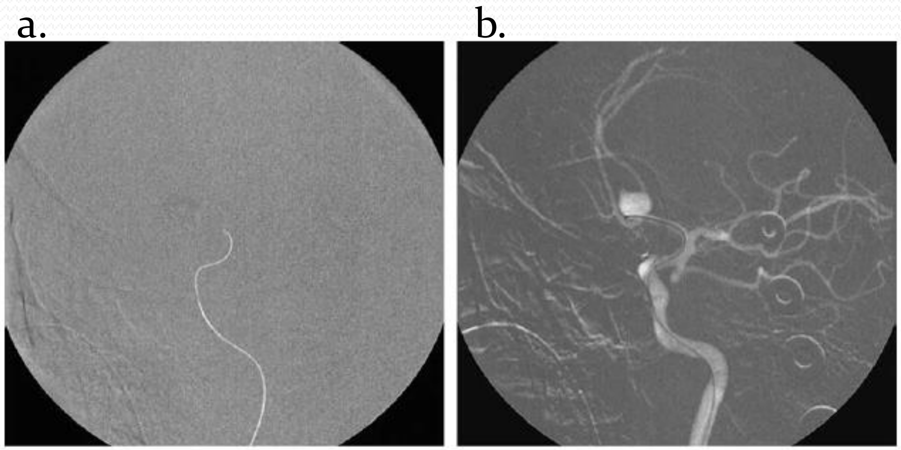


DSA. Cerebral arteriogram (oblique transorbital view) shows an aneurysm of the anterior communicating artery (junction of the A1 and A2 segments of the anterior cerebral artery). **(a) Unsubtracted** original digital fluoroscopic image obtained midway through the contrast material injection. **(b–d) Subtracted** DSA images obtained at three progressive time points during contrast material injection.

Road Mapping

- Road mapping is useful for the placement of catheters and wires in complex and small vasculature.
- A DSA sequence is performed, and the frame with maximum vessel opacification is identified; this frame becomes the road map mask. The road map mask is subtracted from subsequent live fluoroscopic images to produce real-time subtracted fluoroscopic images overlaid on a static image of the vasculature

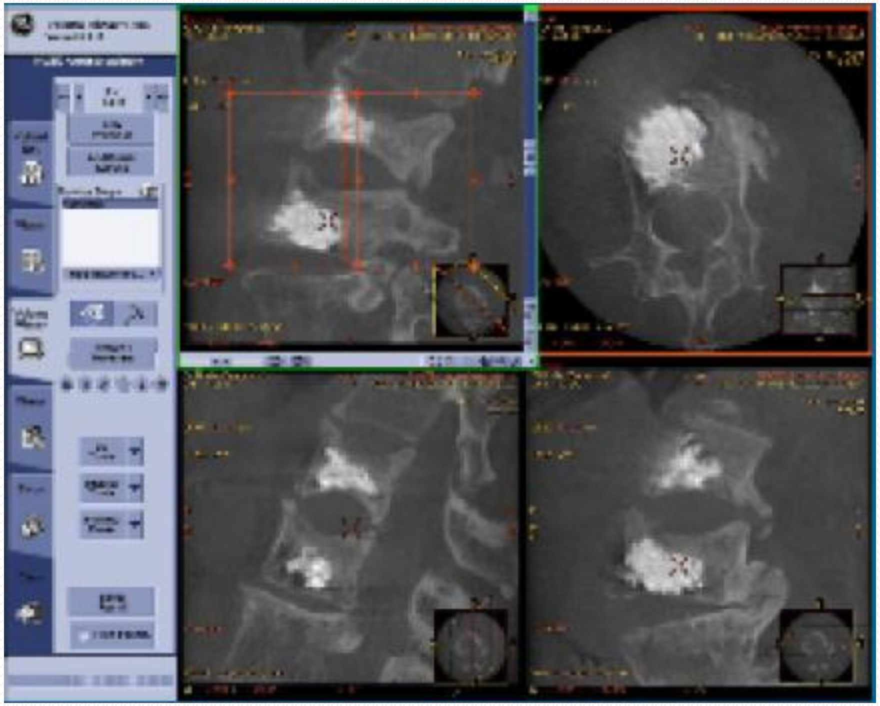




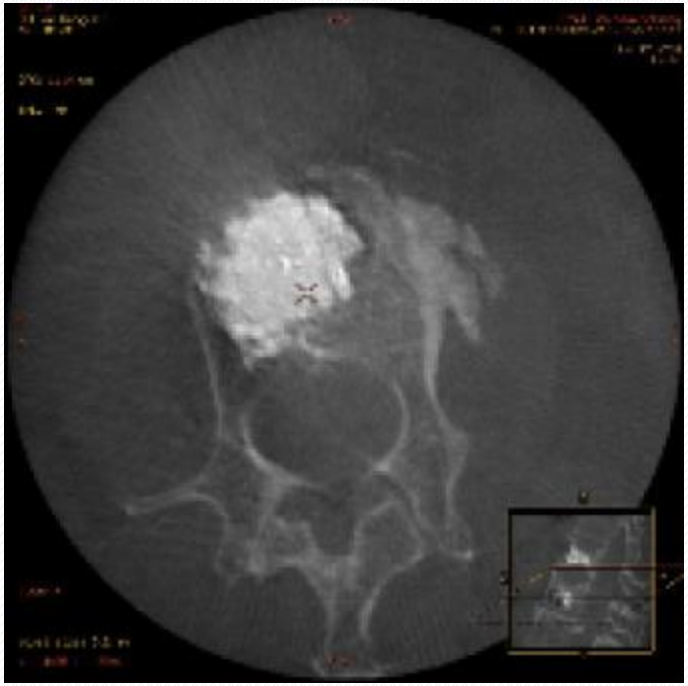
Use of road mapping with clinical images. **(a) DSA image of a wire obtained without road** mapping. It is more difficult to maneuver the wire through the vessels when the path of the vessels cannot be visualized.
(b) Image of the wire obtained with road mapping. Real-time images of movement of the wire overlaid on a static image of the vessels facilitate guiding the wire through vessel turns.

Cone beam CT

Oblique cross-section Axial cross-section



Sagittal cross-section Coronal cross-section



Full screen axial cross-section

Image Quality in Fluoroscopy

- High-contrast (spatial) Resolution
  - Smaller FOV's improve the spatial resolution of image intensifier fluoroscopy system
  - The spatial resolution of FPD fluoroscopy system depends on Pixel pitch
  - Focal Spot Size Blur and Geometry
  - Pixel Binning
- Low-contrast Resolution
  - Scattered X-ray and Grids
  - kVp and Filtration Effects
  - Collimation prevents the irradiation of extraneous tissues and improves image contrast
  - Image Processing
  - Contrast Media (eg. barium, air, iodine)
- Temporal Resolution
  - Frame Averaging – motion blur
  - Pulsed Fluoroscopy reduces patient motion blur in the image
- Noise
  - Radiation Dose and Mottle (high Radiation Dose lower quantum mottle improves the visualization of low contrast structure in the image)

Operating Mode Variables

- kVp
- Effective mA
- Pulsed width
- Variable beam filtration
- Focal Spot

Performance Metrics for Clinical Imaging

- **Requirement**
  - X-Ray Source Efficiency: High continuous power capability, range of spectral filters
  - Image Detector Efficiency (DQE): High X-ray Conversion Efficiency, Low Readout Noise
  - Wide Dynamic Range: High min/max signal range from image detector plus specialized image processing to present information effectively on display.
  - Temporal Response: Fast Readout, low lag, range of frame rates & exposure times

- **Clinical Benefits**
  - High Dose Efficiency High fluoro penetration capability for large patients
  - High Image Quality: Object detectability, High Dose Efficiency
  - Visualize contrast differences from thin to dense anatomy. No Blooming in thin anatomy: robust, forgiving to difficulties with positioning, collimation, contour filters, etc.
  - High definition of moving objects Good rendering of dynamic events

Automatic Exposure Control Systems: “Trajectory” Table-Based: Typical Optimization Criteria

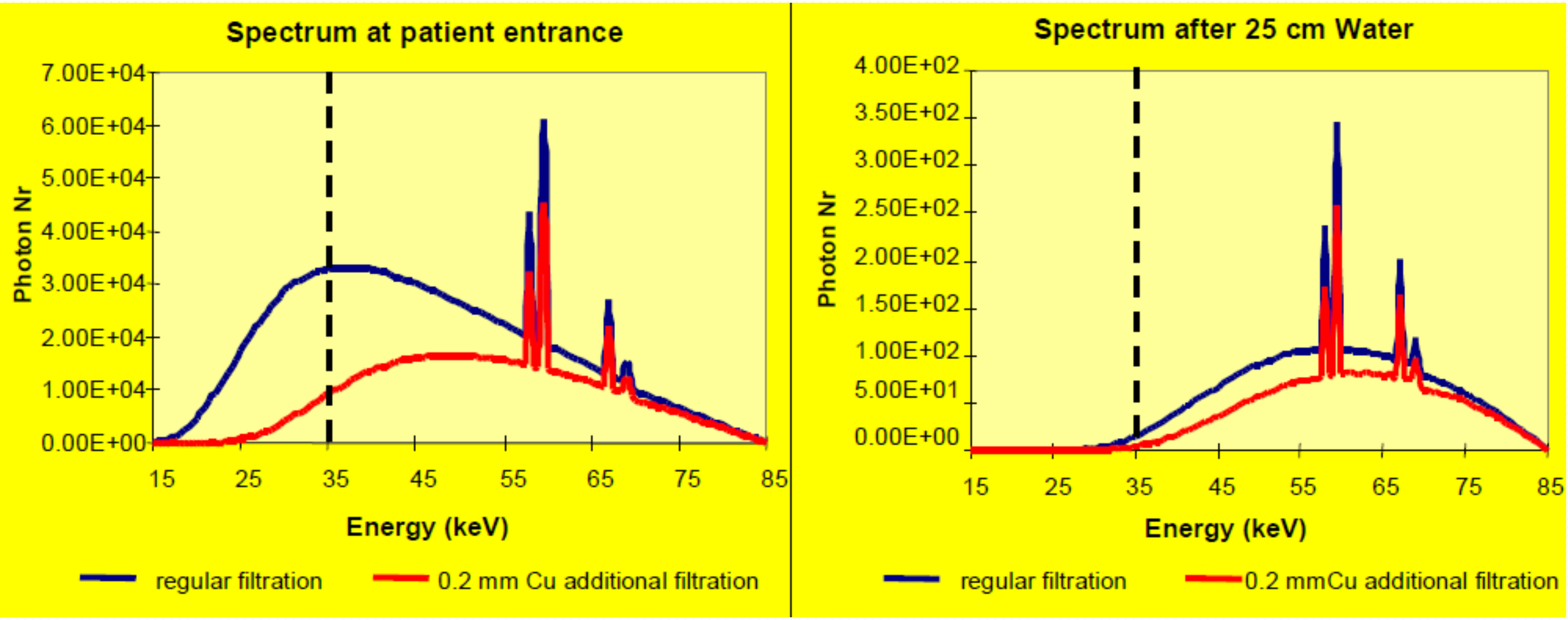
- **Object Contrast:** Difference in x-ray intensity due to the presence of the stent or other device, iodine in artery, barium in colon, etc.

- **Background Noise:** Normal statistical variation in background intensity due to finite number of x-rays used to image

- **Image Quality** =Contrast (more is better)/Noise (less is better) = CNR
  - Cost = Patient Skin Dose

- **Design Strategy:** One of several possibilities: Maintain near-constant CNR over range of patient thickness (within limits) Significant dose savings on small patients & shallow angles
- **Provide several levels of CNR (and therefore dose) to Operator:**
  - Operator chooses level of IQ required for procedure: via protocols, tableside control, initial system setup (trajectory family) Minimize patient dose required to achieve selected CNR by optimizing x-ray technique and filtration.
  - Pediatric: Limit Pulse width to 4 msec max in fluoro and digital cardiac record

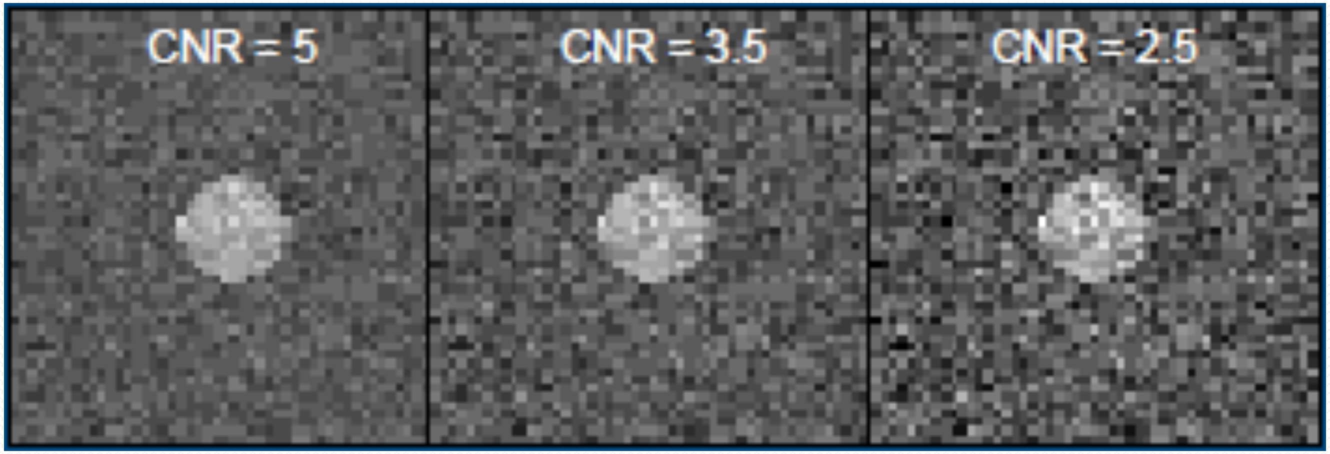
Spectral Filtration



- Softer radiation does not contribute significantly to image
- Spectral filtration eliminates this radiation before it reaches the patient
- Requires higher XRT power to be effective.

Performance Metrics: Detector: Importance of DQE

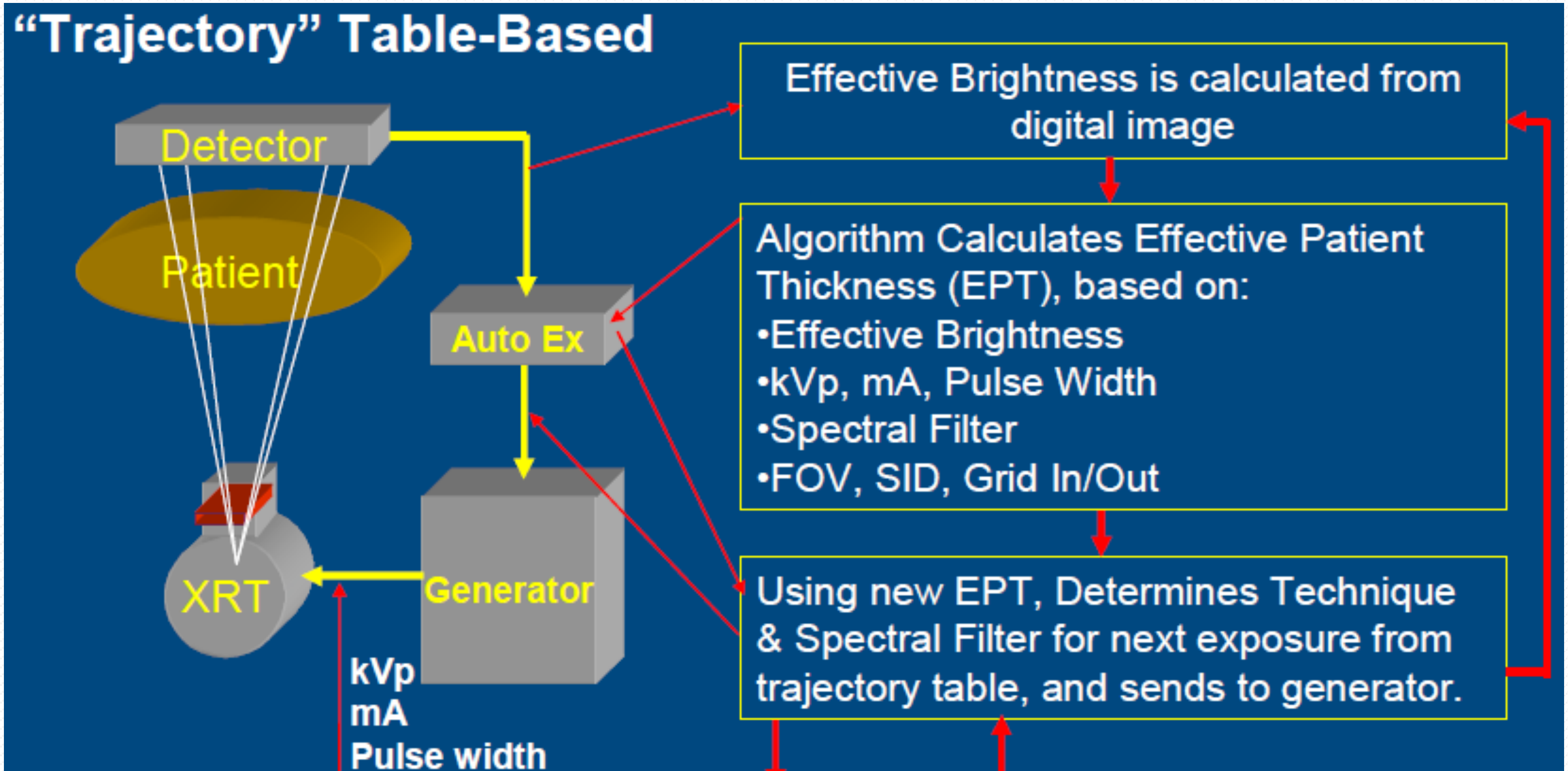
DQE=1.0 DQE = 0.5 DQE = 0.25



Options enabled by higher DQE: Better Image, Same Dose
Same Image, Lower Dose

DQE (Detective Quantum Efficiency) is judged the best index of object detectability in contrast & dose-limited imaging, as in real clinical imaging.

Automatic Exposure Control Systems

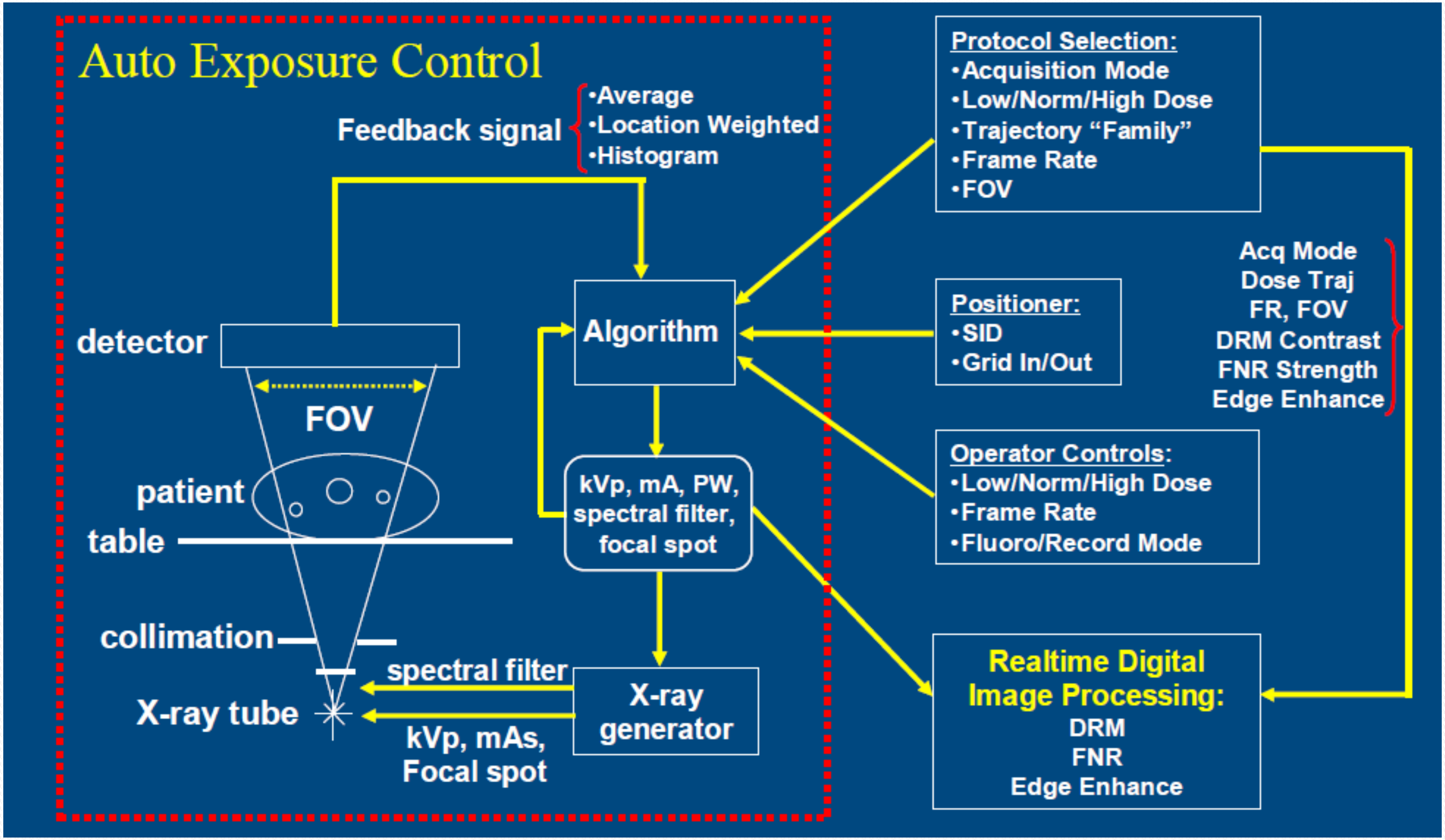


Fluoro: 30 PPS, Normal Detail, 'Smart IQ' Trajectory

EPT	Technique				Pat Dose	Det Dose
Cm	kVp	pw	mA pk	Filt	R/min	mR/min
15	73	8.0	8.3	0.2	0.41	3.6
20	73	8.0	27.4	0.2	1.29	3.6
25	77	11.8	36.6	0.1	4.16	3.6
30	95	12.4	34.3	0.1	10.00	3.6

Benefits: Flexibility, Optimization, Upgradeability

Procedure Protocol-Driven Customization and Control



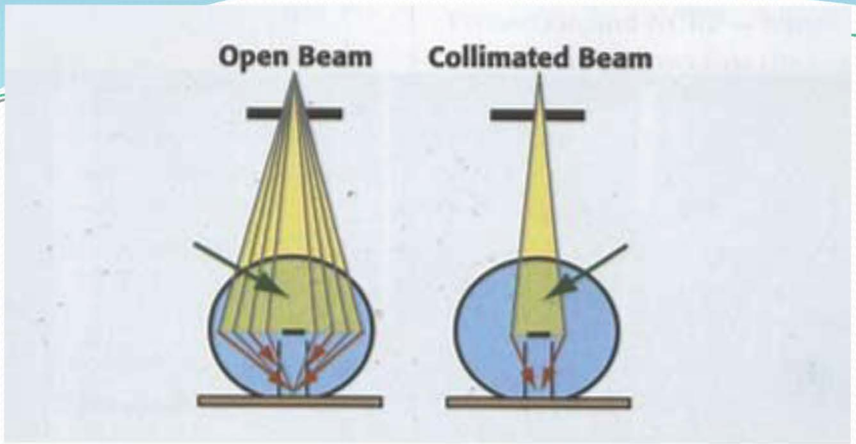
FNR: Fluoro Noise Reduction, DRM: Dynamic Range Management

Factors which Affect Patient Dose

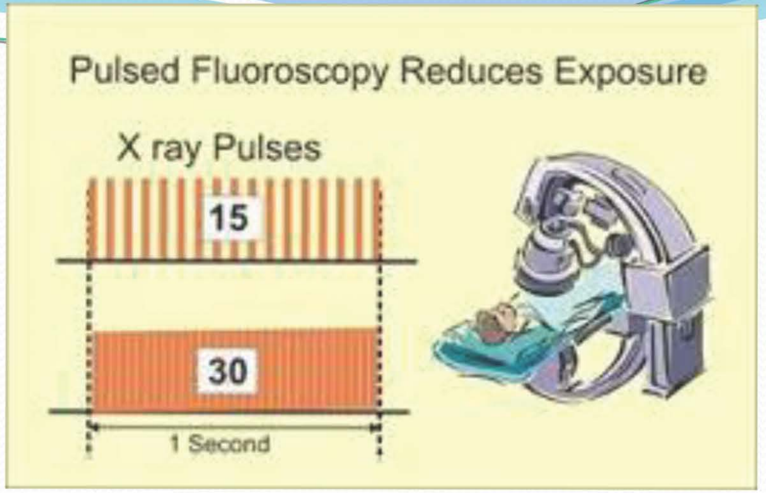
- Geometry – The image receptor should be placed as close to the patient as reasonable in order to minimize the radiation (Most fluoroscopy system track the SID and increase the radiation levels to compensate for and increased distance)
- Dose Level selection; Low, Normal, and High
- FOV selection – Smaller FOV's utilize more radiation
- Automatic Brightness (Dose) Control (ABC) systems – selection of kVp, mA setting, x-ray beam filtration, pulse width.
- X-ray Beam Filtration
- kVp Selection (Higher kVp's result in lower patient doses)
- Pulsed Fluoroscopy
- Duration of Fluoroscopy Time
- Removal of Grid at less than 10 cm thickness of patient

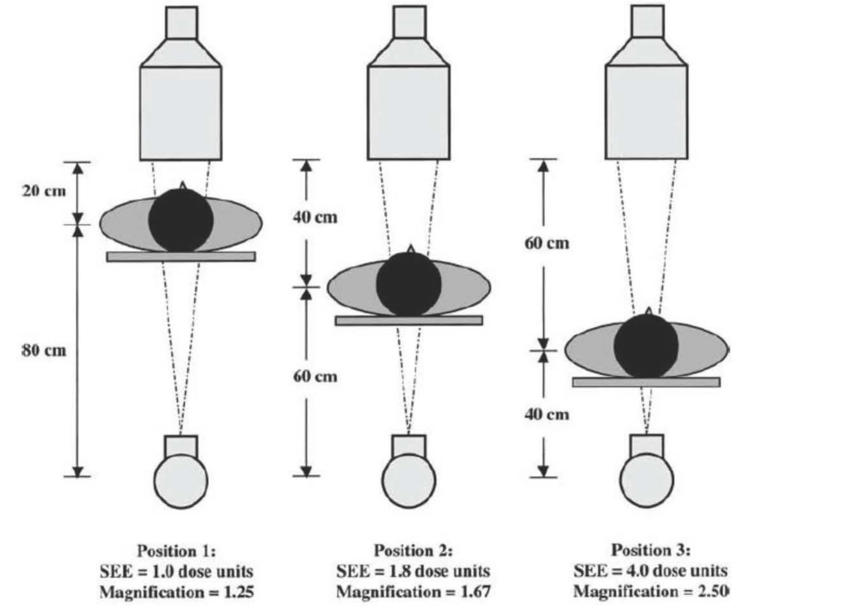
Factors which Affect Staff Dose

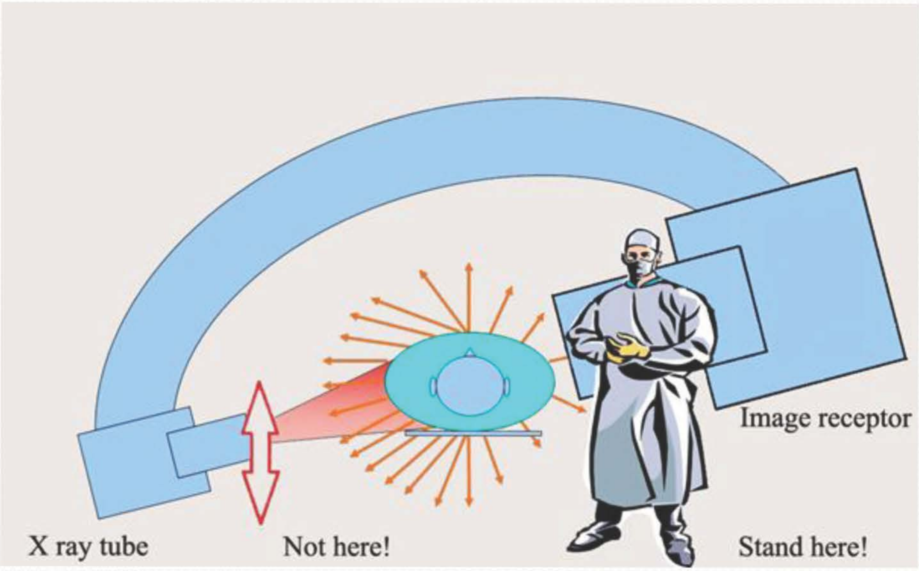
- Exposure Time
- Distance from the radiation source
  - Reduce the patient to receptor distance, increase the x-ray tube to patient distance(Saving dose to the patient is saving dose to staff)
  - Geometry-PA position with x-ray tube under the table
  - X-ray Tube side has higher the scattered radiation
- Shielding
  - Personnel protection-lead apron, lead glasses
  - Under table lead drape
  - Overhead protective shield



Limiting beam size reduces the amount of tissue that gets irradiated, thereby reducing scatter. Collimation also improves the view because scatter degrades image quality.







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- Fluoroscopy and Radiation Safety Content for Radiologists, Marta Hernanz-Schulman MD, FAAP, FACR, Keith Strauss, M.Sc, Ishtiaq H. Bercha, M.Sc http://www.imagegently.org/Portals/6/Radiologists/Background4radiologists.pdf