Fluoroscopy 1
Fluoroscopy Equipment

Jeom Soon Kim, Ph.D. DABR.
Diagnostic Medical Physicist
Department of Radiology
Brigham and Women's Hospital
Email: jkim90@partners.org

Surgical operation during World War I using a fluoroscope to find embedded bullets

The photo is credited to Dr. J. P. Hoguet, a surgeon at the Roentgenographic Dept. of the American Ambulance Hospital at Neuilly, France.

Why Use Fluoroscopy

- Dynamic Temporal Studies
  - swallowing, cardiac pulsation and other processes.
  - Position guide for placing catheters and for selection of a location to do spot film radiographic images or DSA imaging.
- Instantaneous and Panoramic Views
  - To visualize areas of trauma quickly for foreign bodies, bleeding and other internal damage.
  - To quickly examine contrast filled vessels for malformations, stenosis or aneurisms.

Fluoroscopy Systems

Gastrointestinal(GI) Fluoroscopy Unit

Combined Radiography and Fluoroscopy (R&F)room
Ex. BWH Diagnostic imaging room 17.

Fluoroscopy Flat panel detector

Radiography table detector

Radiography X-ray tube

Fluoroscopy tube under table

Fluoroscopy Systems

C-arm Mobile Fluoroscopy Units

A typical use for this unit is to assist with orthopedic joint replacements, endoscopy procedures and colonoscopy.

- BWH Ambulatory room 8

C-arm x-ray tube

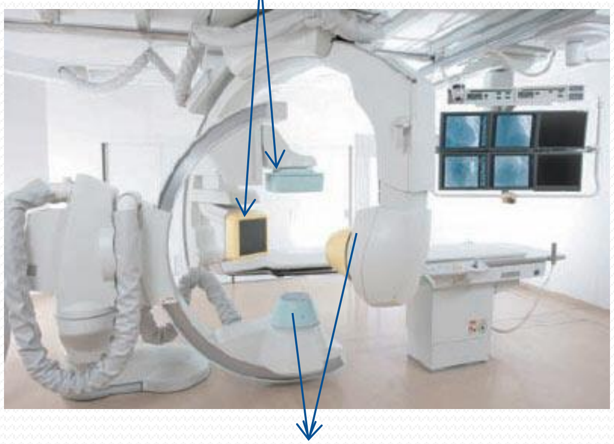
C-arm Image Intensifier

C-arm control panel with monitors

Interventional Fluoroscopy Systems

Interventional fluoroscopy systems are used in Angiography rooms, Neurointerventional rooms, Cardiac Cath Labs and Electrophysiology Labs

Flat panel
Image Receptors



X ray Tubes

Biplane fluoroscopy systems have two C-arms each with an x-ray tube and image detector, while single plane systems have one C-arm only.

BWH Neurointerventional room 1

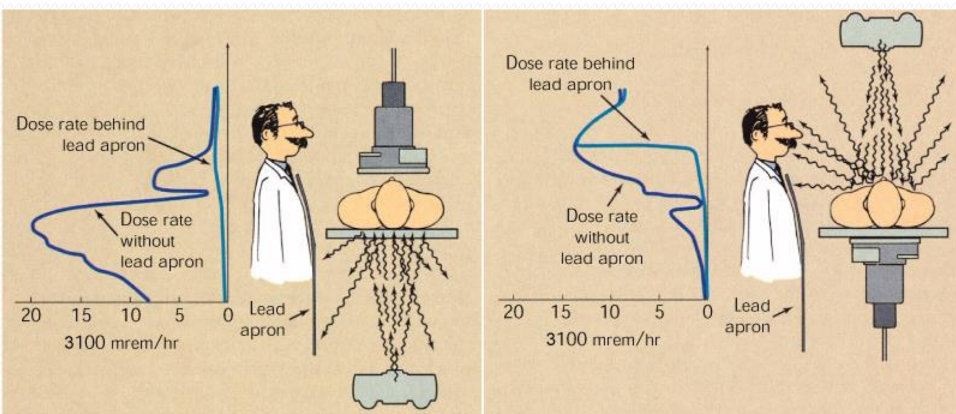
Fluoroscopy Systems

Urological Fluoroscopy Units

X-ray Tube
above the table

Image Receptor
below the table

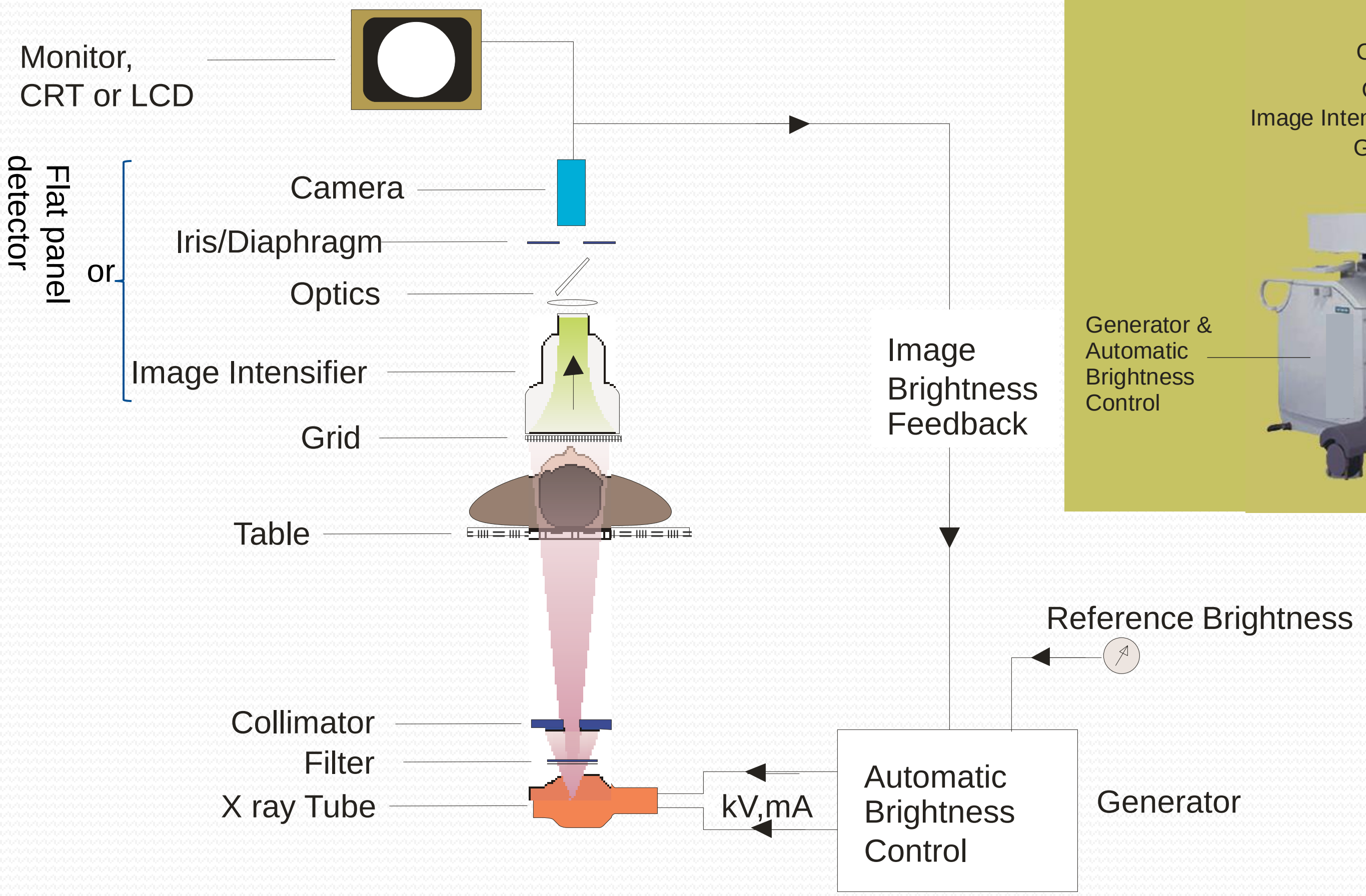
This configuration places the kidneys and bladder closer to the image receptor, which reduces focal spot blur.

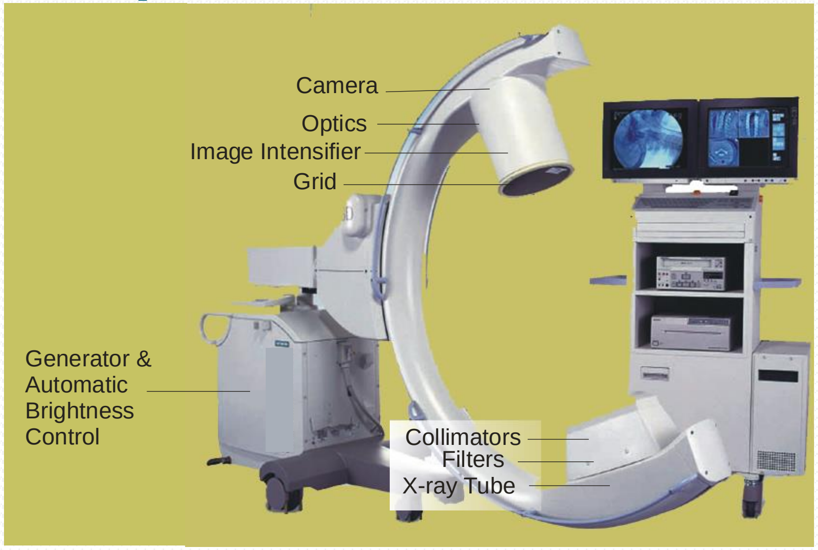


Remote Controlled Fluoroscopy Units

The system configuration with X-ray tube up and image receptor down makes more radiation scattering to practitioner’s eye level, so the remote control unit is designed for radiation protection

Fluoroscopy System Components

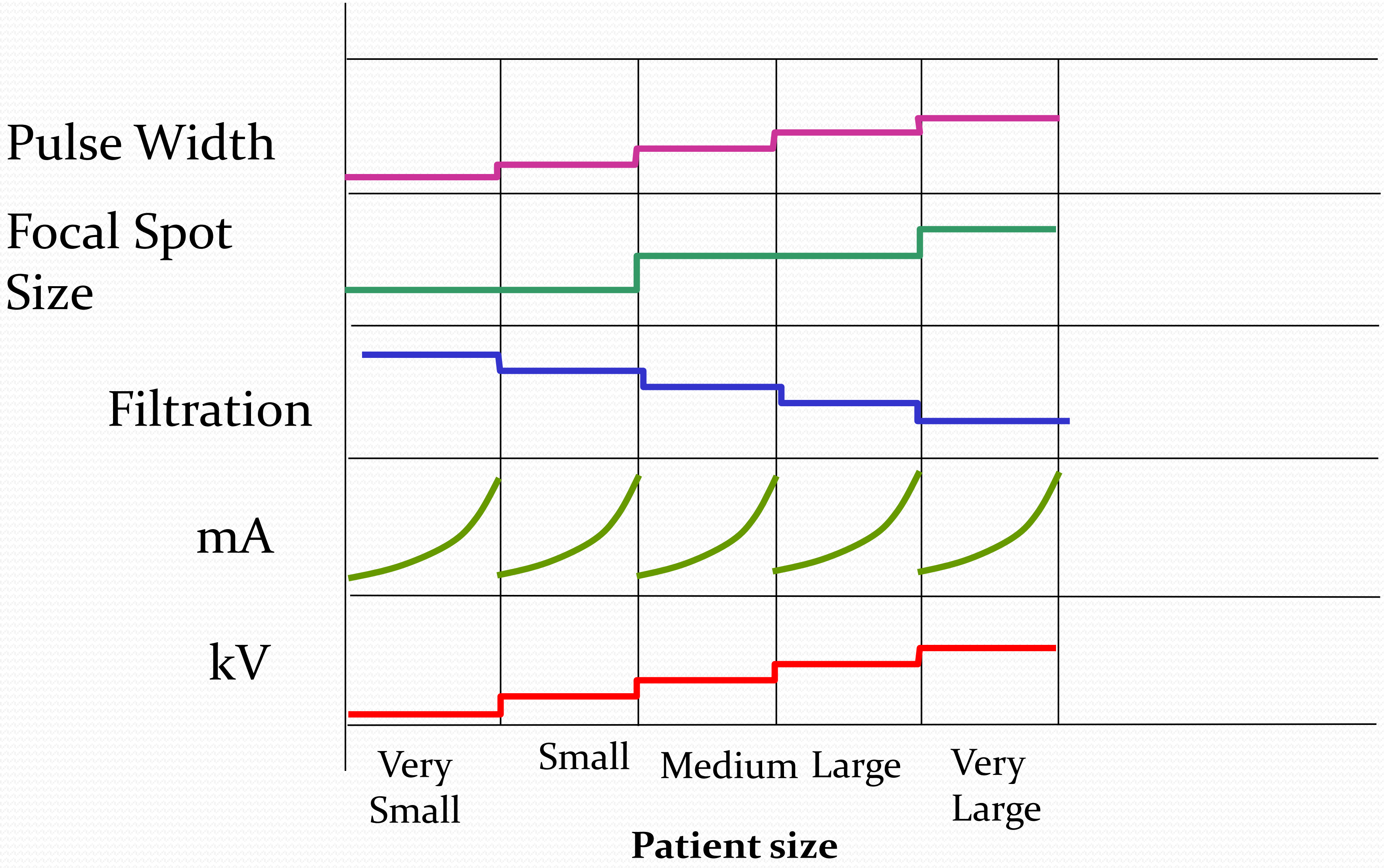




Fluoroscopy System Components

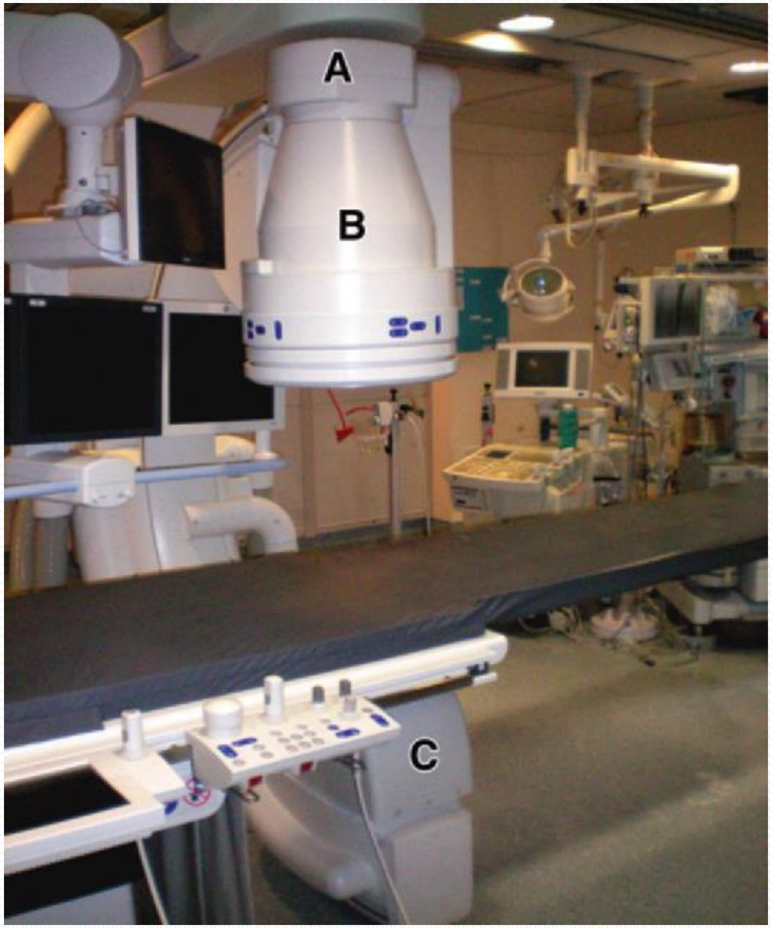
- X-ray Generator - High voltage generator, extra heat capacity
- X-ray Tube - 0.3 mm to 1.0 mm or 1.2 mm sized focal spot
- Beam filtration - Al or Cu filters, Wedge filters
- Collimation - Circular and rectangular collimator
- Patient Table and Pad - High strength, minimal radiation absorption and comfort
- Anti-Scatter Grid - 6: 1 to 10:1, circular (XRII systems)or rectangular (FPD systems)
- Image Receptor – Image Intensifier (Lens, Aperture, TV camera) or Flat Panel Detector
- Television or Video Display Monitor (VDT), LCD Monitors
- ABC (Automatic Brightness Control) or ADC (Automatic Dose Control)

Automatic Exposure Control and Patient Thickness



Fluoroscopy System Components

X-ray Image Intensifier



Photograph of an angiography room shows a fluoroscopy system with an image intensifier (*B*) *(field of view [FOV], 40 cm) and television camera (A). C = x-ray tube.*

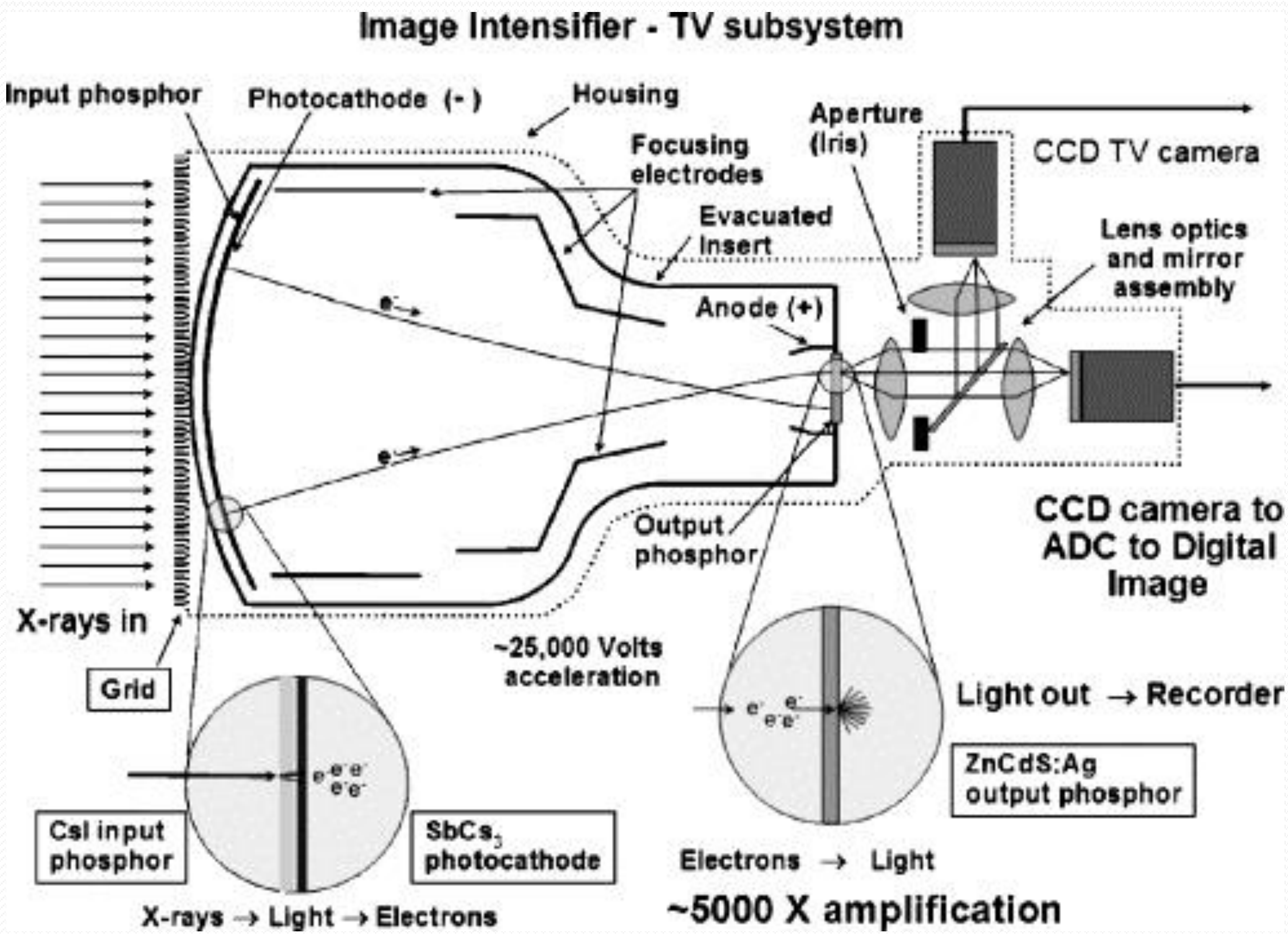
Fluoroscopy System Components

X-ray Image Intensifier

- Convert X rays into visible light
- Increase the image brightness so it is visible to the camera and recording devices

Fluoroscopy System Components

X-ray Image Intensifier



Fluoroscopy System Components

X-ray Image Intensifier

MEASURES OF IMAGE INTENSIFIER EFFICIENCY

BRIGHTNESS GAIN =MINIFICATION GAIN x FLUX GAIN

MINIFICATION GAIN is defined as the ratio of the square diameter of the input phosphor to the square diameter of the output phosphor: $(d_i / d_o)^2$

FLUX GAIN The ratio of the number of light photons created at the output phosphor to the number of x-ray photons striking the input phosphor. This can vary by as much as 3000:1.

EXAMPLE The diameter of the input phosphor is 9 inches. The diameter of the output phosphor is 1 inch.

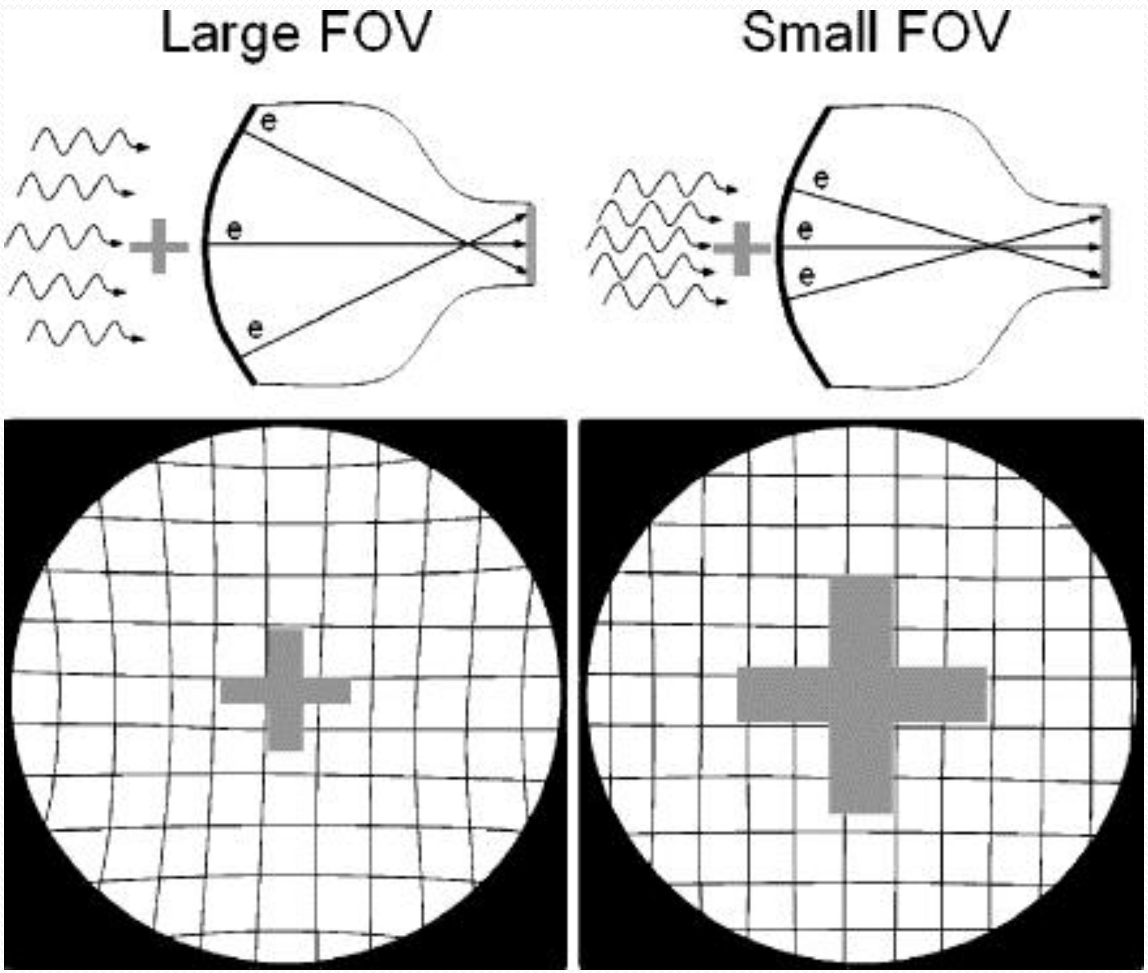
MINIFICATION GAIN $=9^2/1^2= 81$

FLUX GAIN=3000

BRIGHTNESS GAIN =81x3000=243000

Fluoroscopy System Components

X-ray Image Intensifier-Field of View



- Less minification gain
- Higher patient dose
- Better spatial resolution
- Reduced geometric pin-cushion distortion

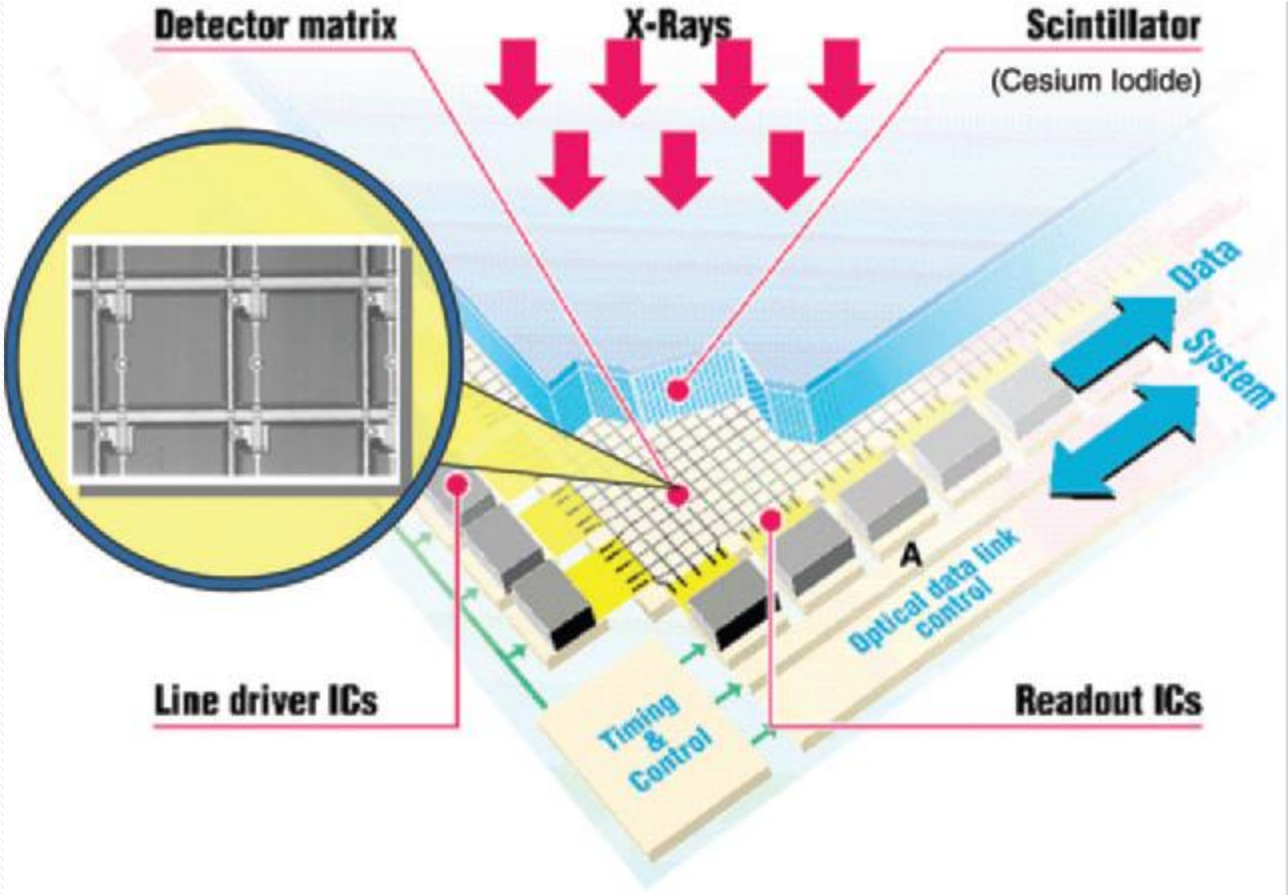
Fluoroscopy System Components
X-ray Image Intensifier-image distortion

- Pin- cushion distortion
- S- distortion
- Veiling glare (glare extending from very bright areas)
- Vignetting (loss of brightness at periphery).
- Lag
- Saturation

Flat Panel Detector System

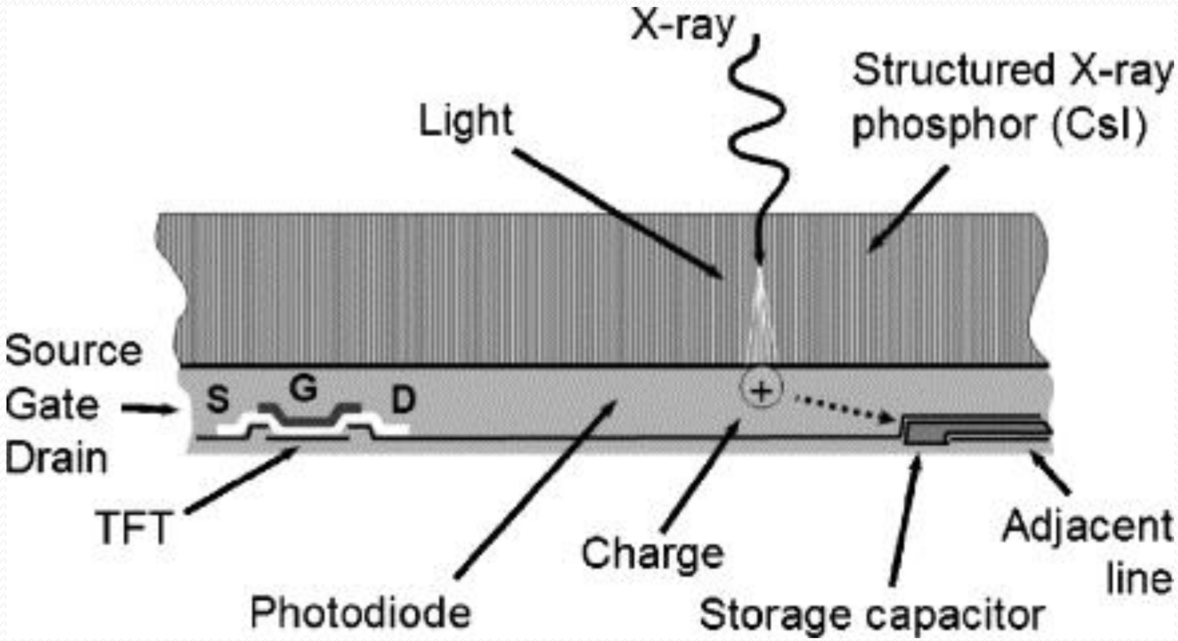
a large FPD fluoroscopy system. *A = flat-panel image receptor, B = x-ray tube*

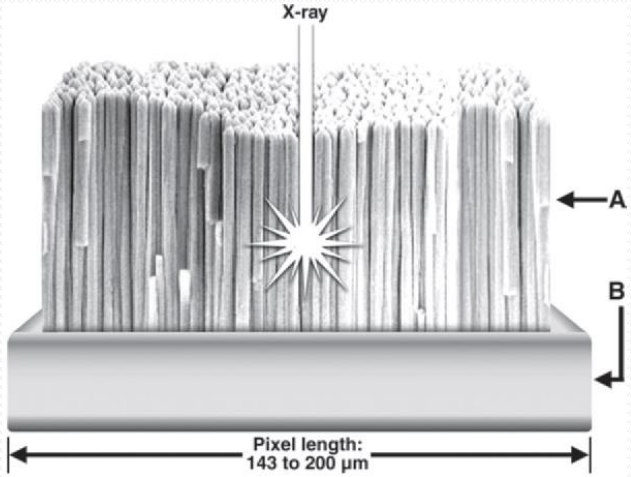
Flat Panel Detector System



Construction of an FPD array. **Drawing shows a section of the FPD and many individual DELs.** ***A = 14-bit A/Ds, IC = integrated circuit.***

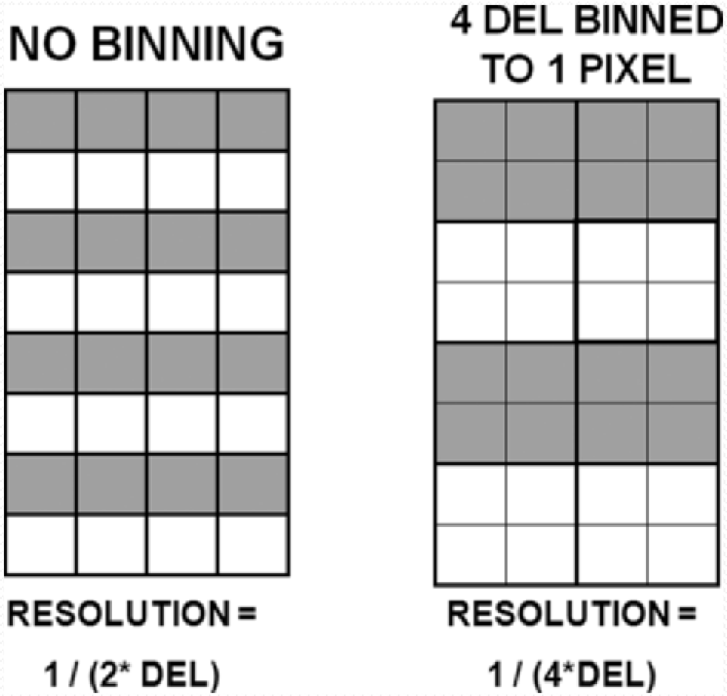
Flat Panel Detector System





Cross-section of an indirect TFT detector using CsI structured phosphor shows the conversion of X-rays first into light, traveling through the structured phosphor to a photodiode etched on the TFT array, and the creation of a proportional charge stored in the local capacitor

Flat Panel Detector System



Amount of Data and Data Rates for FPD Arrays of Different Sizes

FOV (cm)	No. of DELs* (Pixels)†	Image Size*(MB)	Data Rate‡ (MB/sec)
10 × 10	0.25	0.5	15
20 × 20	1.0	2.0	60
30 × 30	2.25	4.5	135
40 × 40	4.0	8.0	240

*Assumes 2 bytes per DEL. DEL size is 200 µm on each side.

†Data are in millions.

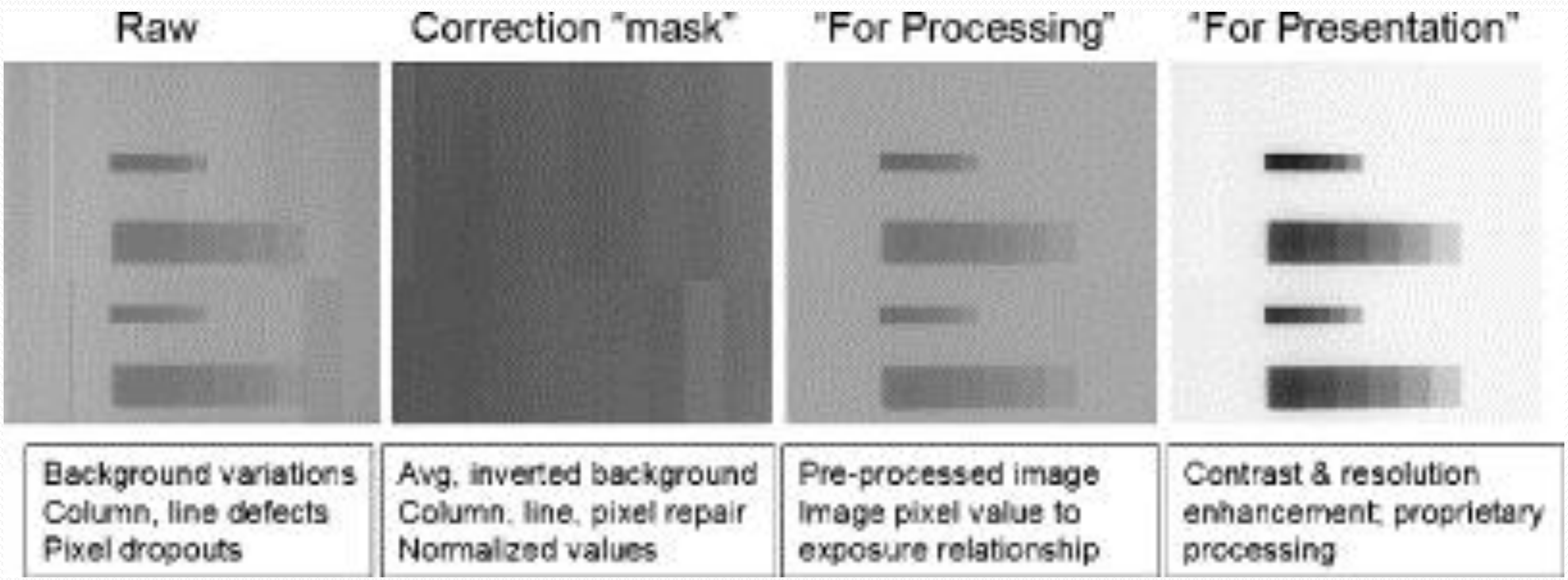
‡All data rates are at 30 frames per second.

Diagrams illustrate binning. By grouping four DELs together, the data rate is reduced and the surface area is increased. However, the spatial resolution to display line pairs is also reduced.

Flat Panel Detector System

- Spatial Resolution = 1/ 2x DEL (mm) in LP/mm
- If there is no binning, the spatial resolution is the same in all FOV's of FPD systems
- The typical spatial resolution of most current FPD image receptors is about 2.5 – 3.0 LP/mm for all FOV's

Flat Panel Detector System
Image processing



Left ‘Raw–uncorrected flat-panel image of step wedges.*Center left* Image uniformity corrections for a FPD are possible by first mapping non-functional detector elements, columns and rows with replacement of nearest-neighbor average values and the creation of an inverted correction ‘flat-field–mask of normalized values. *Center right* Application of the flat-field mask to the uncorrected image produces the ‘for-processing–image. *Right* Image processing through contrast and spatial resolution enhancement results in the ‘for-presentation–image

Image Distortion -FPD

- Bad pixels
- Correlated Noise
- Persistence – lag or ghosting

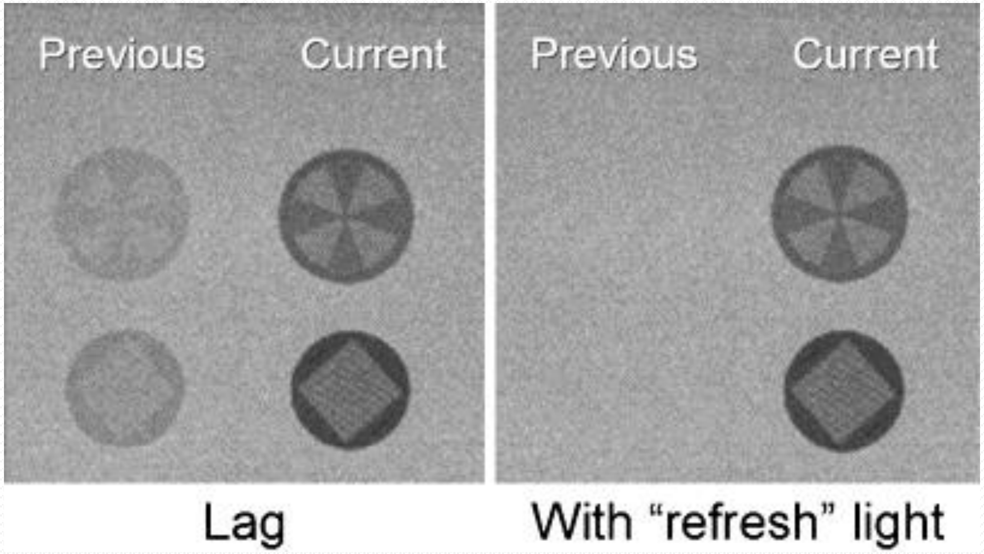


Image lag results from residual signals from previous exposures being superimposed on the current image. The magnitude of the lag can be quite extensive (e.g., 5–0% of the previous signal) and easily observed (left figure). Poor temporal resolution and potential artifacts are drawbacks. Methods such as detector ‘backlighting–are being implemented to reduce or eliminate the residual lag (image from Philips Medical Systems website

Image Process Features

- Last Frame Hold
- Frame Averaging
- Edge Enhancement – improve spatial resolution
- Gray Scale Algorithms – enhance contrast and extend the dynamic range

Image intensifier/TV versus flat-panel detector for fluoroscopy

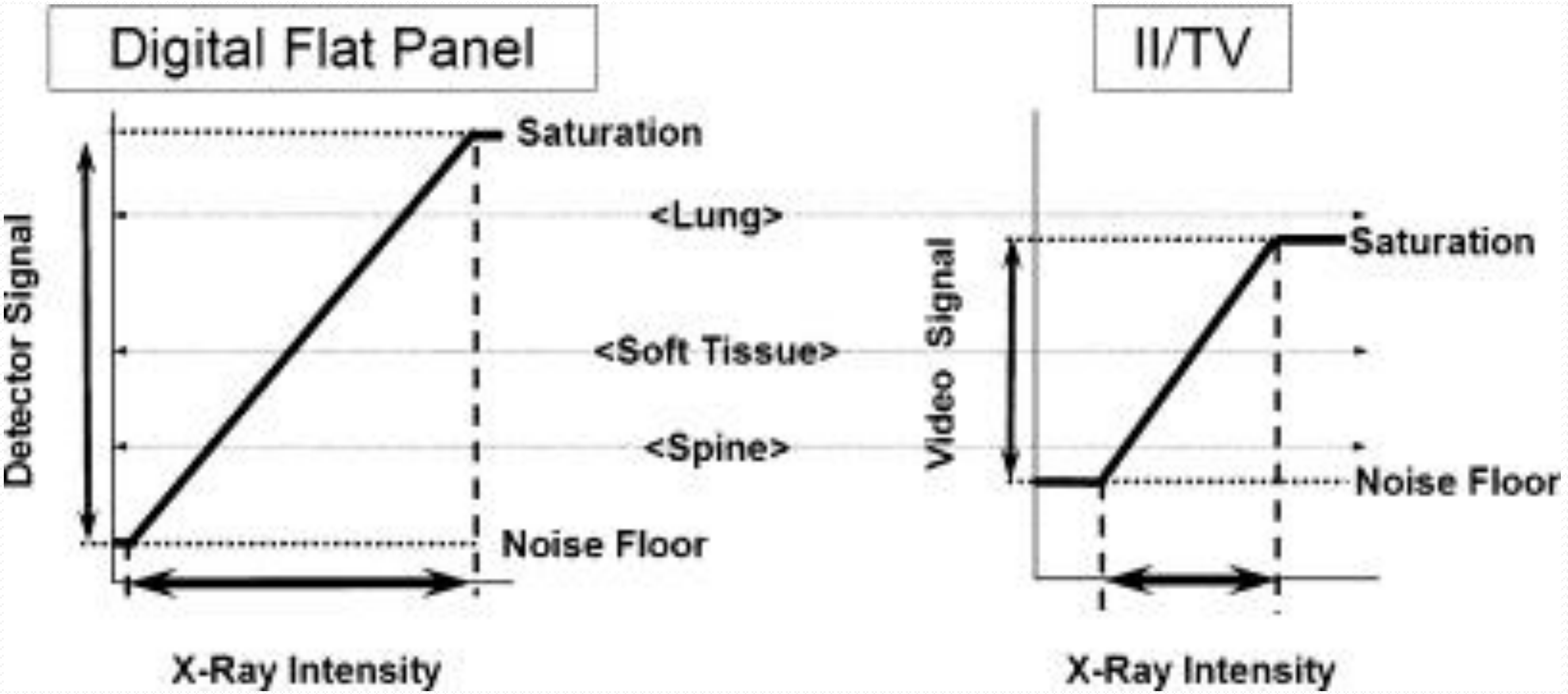
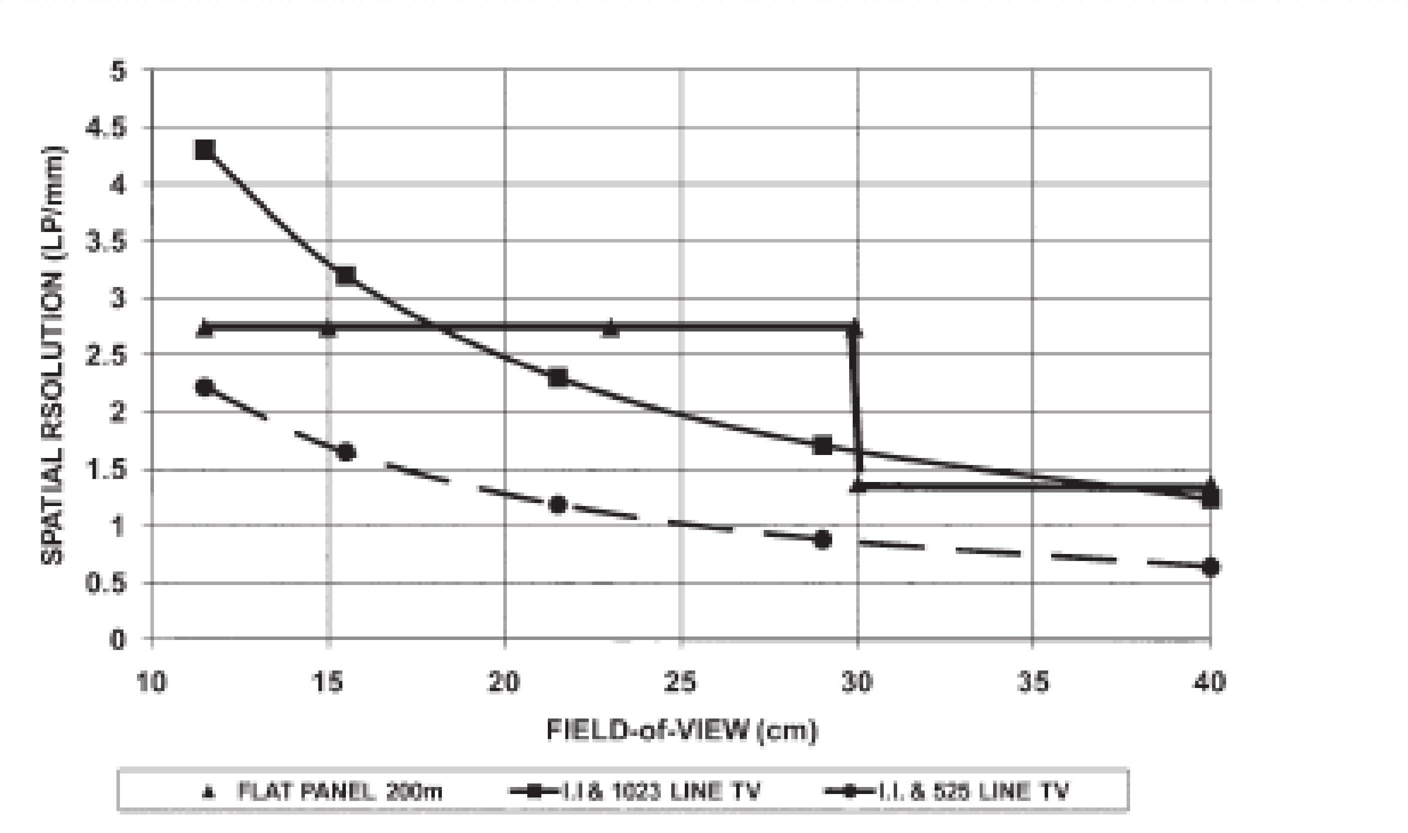
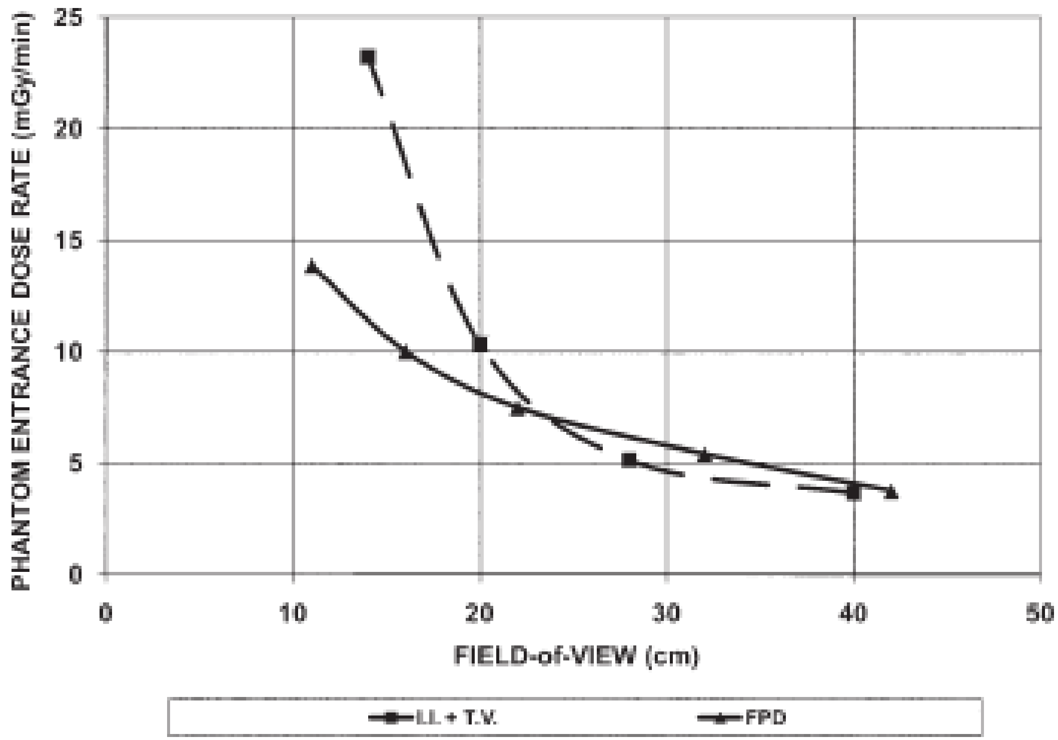


Image intensifier/TV versus flat-panel detector for fluoroscopy; Spatial Resolution



the spatial resolution of both image intensifier (dashed line, solid line with squares) and FPD (solid line with triangles) systems.

Image intensifier/TV versus flat-panel detector for fluoroscopy; Radiation Dose at FOV's



Graph plots the entrance radiation dose rates to a phantom of the image intensifier (dashed line) and FPD (solid line) fluoroscopy systems as a function of the selectable FOVs for a fluoroscopy pulse rate of 15 pps in normal dose mode. The phantom simulates a typical patient.

Image intensifier/TV versus flat-panel detector for fluoroscopy; Image Quality

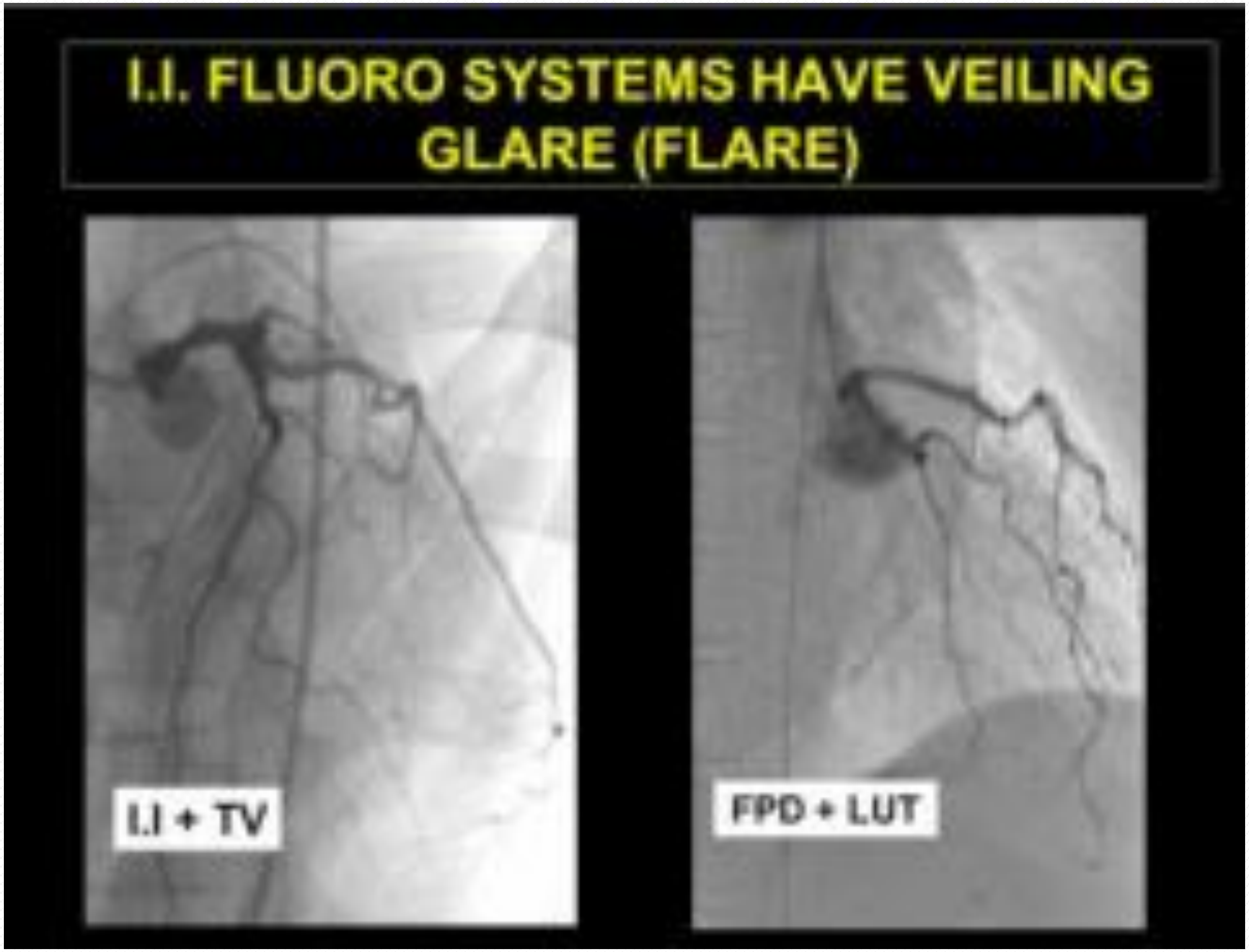
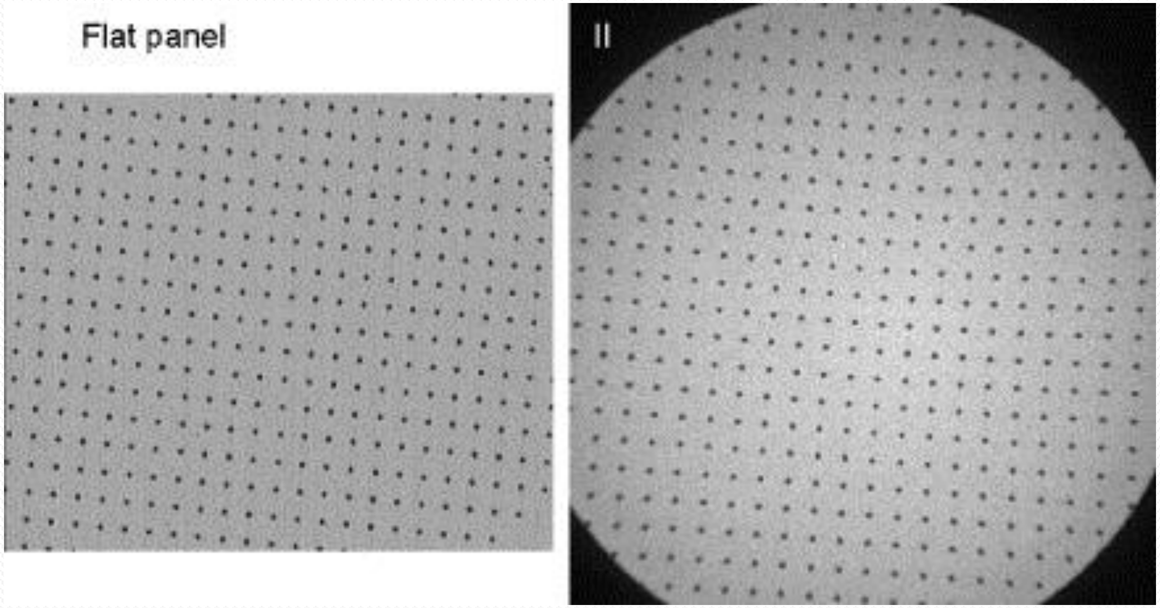
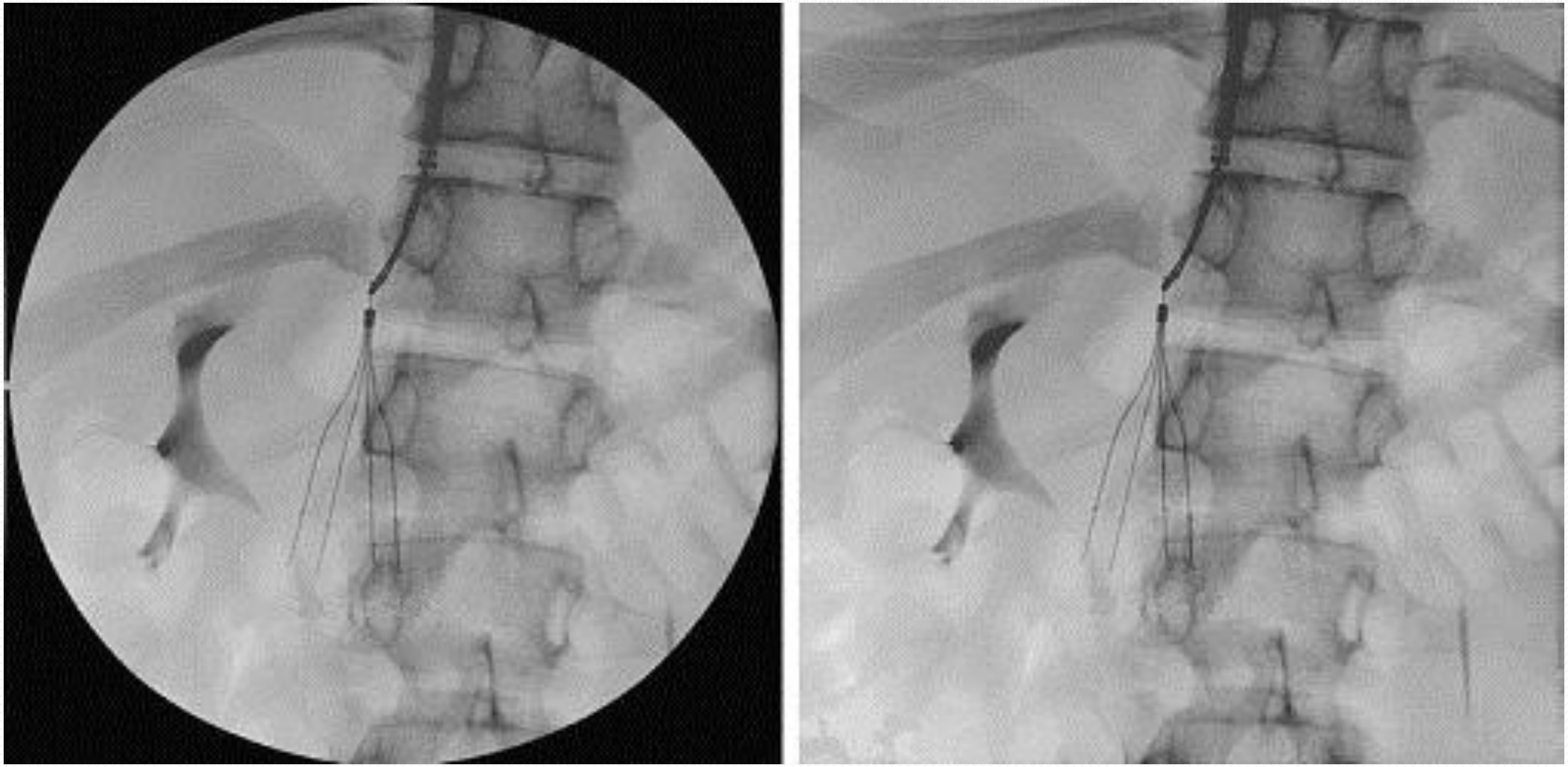


Image intensifier/TV versus flat-panel detector for fluoroscopy; Image Quality



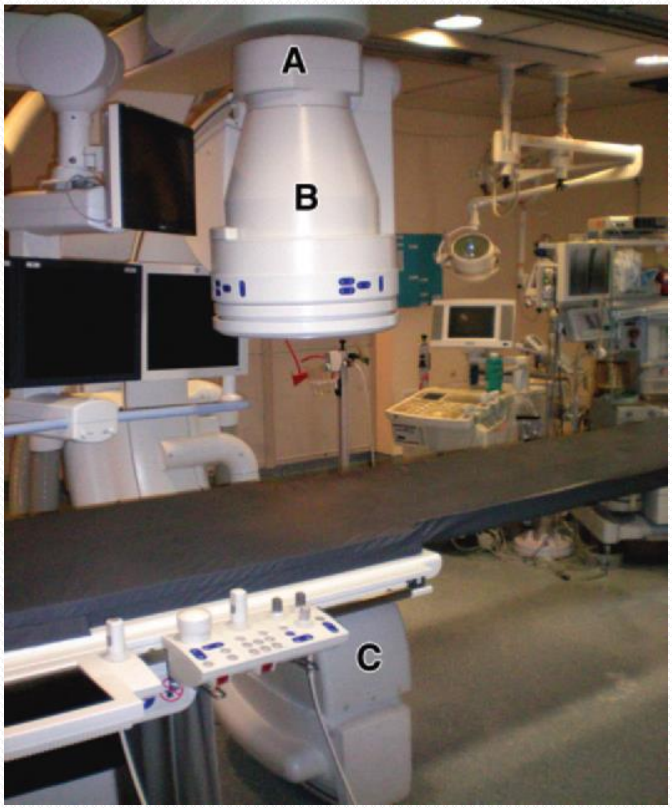
Images of an array of equally spaced radioopaque spheres as imaged by a flat panel fluoroscopy system (*left*) and an II/TV system (*right*) show the lack of geometric distortion by the FPD system

Image intensifier/TV versus flat-panel detector for fluoroscopy



Left An II (and TV) image is inherently circular, which results in inefficient use of a rectangular format image.*Right* A flat panel image provides full FOV, a decided advantage, but circular collimators can (and should) be used with FPD systems to reduce irradiated volume

Image intensifier/TV versus flat-panel detector for fluoroscopy



A comparison of II/TV and corresponding FPD systems for interventional imaging shows the significant reduction in detector bulk and size, providing improved patient access and easier maneuverability

Image intensifier/TV versus flat-panel detector for fluoroscopy

Feature comparison of II/TV and FPD systems

Feature	Digital flat panel	Conventional II/TV
Dynamic range	Wide, about 5,000:1	Limited by TV, about 500:1
Geometric distortion	None	Pin-cushion and ‘S– distortion
Detector size (bulk)	Thin profile	Bulky, significant with large FOV
Image area FOV	41×41 cm	40 cm diameter (25% less area)

Factors which affect Spatial Resolution

- Smaller FOV's improve the spatial resolution of image intensifier fluoroscopy system
- The FOV usually does not change the spatial resolution of FPD fluoroscopy system
- Focal Spot Size Blur and Geometry
- Pixel Binning
- Frame Averaging – motion blur
- Pulsed Fluoroscopy reduces patient motion blur in the image

Factors which Affect Visualization of Low Contrast Structure

- Scattered X-ray and Grids
- kVp and Filtration Effects
- Collimation prevents the irradiation of extraneous tissues and improves image contrast
- Radiation Dose and Mottle (high Radiation Dose lower quantum mottle improves the visualization of low contrast structure in the image)
- Image Processing
- Contrast Media (eg. barium, air, iodine)

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)
- FOV selection – Smaller FOV's utilize more radiation for I.I and FPD.
- Automatic Brightness (Dose) Control (ABC) systems – selection of kVp, mA setting, x-ray beam filtration, pulse width.
- X-ray Beam Filtration

Factors which Affect Patient Dose

- Aperture of an I.I. fluoroscopy system
- kVp Selection (Higher kVp's result in lower patient doses)
- Pulsed Fluoroscopy
- Conversion Gain (The amount of light produced by an I.I. for a given amount of input radiation)
- Duration of Fluoroscopy Time

References

- Schueler BA. The AAPM/RSNA physics tutorial for residents: general overview of fluoroscopic imaging. RadioGraphics 2000;20(4):1115–1126.
- Seibert JA. Flat-panel detectors: how much better are they? Pediatr Radiol 2006;36(suppl 2):173–181.
- Nickoloff EL. The AAPM/RSNA physics tutorial for residents:Physics of Flat-Panel Fluoroscopy Systems. Survey of Modern Fluoroscopy Imaging. Flat-Panel vs. II and More. RadioGraphics 2011;31:591-602.
- Bushberg et. Al. The Essential Physics of medical Imaging, Chapter 9.