Interventional Fluoroscopy Imaging Equipment:

What to Know Before You Buy

Jack T. Cusma,
Mayo Foundation and Clinic

Interventional Fluoroscopy

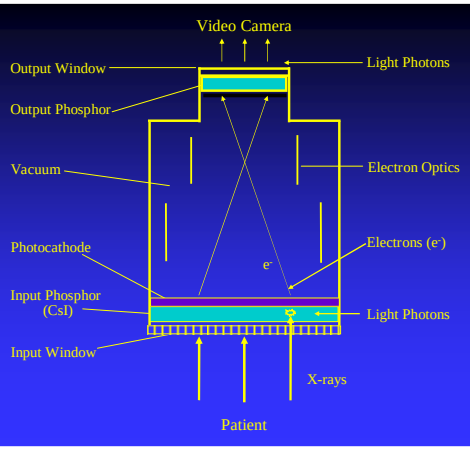
Technology Turning Point?

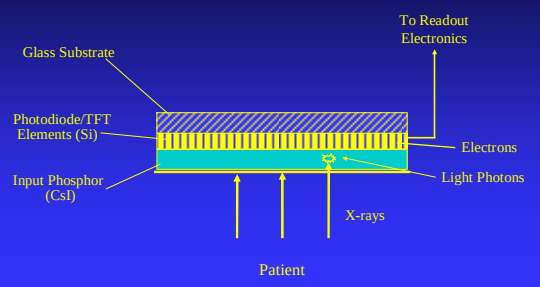
- Product Development Cycle
  - 5-7 years
- Purchase Cycle
  - approx 7 years

Need to maximize technology investment

Fluoroscopy: Image Detectors

Revolution or Evolution?





Flat Panel Detectors

Improved Image Quality

- Spatial Resolution
- Contrast Resolution
- Dynamic Range
- Lower Distortion

MAYO CLINIC AAPM 08/02/2006

Interventional Fluoroscopy

FPD or I.I.?

- Detector is only a component
  - Imposes constraints along with benefits
- Need to look at all factors
  - Technology options
  - Local requirements
  - Workflow needs

MAYO CLINIC AAPM 08/02/2006

Interventional Fluoroscopy

Clinical Requirements

- Procedure types to be performed
  - Neurovascular
  - Cardiac
  - Peripheral vascular
  - Pediatric
  - Diagnostic vs. Intervention

MAYO CLINIC AAPM 08/02/2006

Clinical Functionality

Field-of-View

- Fewer options with FPD
  - 20x20 cm
  - 30x30 cm
  - 30x40 cm
  - 40x40 cm
  - 3 to 5 FOV choices
- Not a circle!

Clinical Functionality

Field-of-View

- Fixed pixel size
  - 0.15, 0.18, 0.20 mm
- Fixed spatial resolution?
  - Binning?
  - Dependent on acquisition rate
  - Image processing modification

Clinical Functionality

Acquisition Rates

- Vascular Applications
  - <= 7.5 frames/sec
- Cardiac
  - 15 and 30 frames/sec
- Pediatric
  - 60 frames/sec
- Biplane
- Effects on spatial resolution

Clinical Functionality

Acquisition Matrix and Pixel Size

- Not all resolutions available in all FOV
  - e.g. 30x40 cm detector
  - 2480x1920 @ full resolution, full FOV
  - .154 mm pixel (?)
  - 2x2 binning -> .308 mm
  - 4x4 binning -> .616 mm
- Depends on Fluoro vs. Record, frame rate, FOV, installed options!

Clinical Functionality

Acquistion Matrix and Display Zoom

- Reduced FOV -> Smaller matrix
  - Mag 3 on 30x40 detector
    - 16x16 cm (22 cm FOV)
    - 1024 x 1024 acquired matrix
    - 1X zoom to display
  - Mag 4
    - 11x11 cm (16 cm FOV)
    - 720 x 720 acquired matrix
    - 1.4X zoom to display

MAYO CLINIC

AAPM 08/02/2006

Clinical Functionality

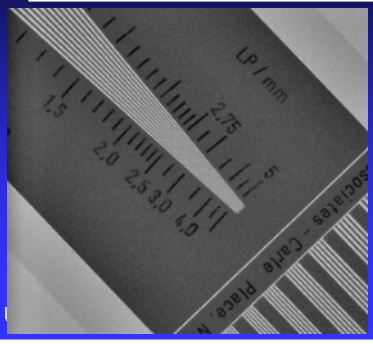
Acquistion Matrix and Display Zoom - I.I.

- 30 cm I.I.
  - 22 cm FOV
    - 1024x1024 acquired matrix
    - 0.15 mm pixel
    - 1X zoom to display
  - 16 cm FOV
    - 1024x1024 matrix
    - 0.11 mm pixel
    - 1X zoom to display

MAYO CLINIC

AAPM 08/02/2006

Flat Panel Spatial Resolution



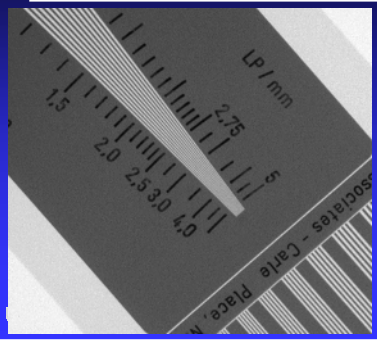
1024 x 1024

3.3 - 3.5 lp/mm

0.184 mm pixel

AAPM 08/02/2006

I.I./CCD Spatial Resolution



1024 x 1024

4.3 - 4.5 lp/mm *

0.110 mm pixel

(* 5 in. FOV)

AAPM 08/02/2006

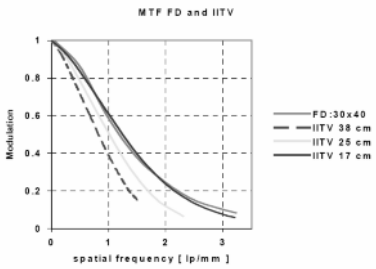


Figure 5: MTF curves of FD and IITV

Bruijns, SPIE 2002

Clinical Functionality

Acquisition Matrix and Display Resolution

- Image processing also a factor
- Multiple processing options
  - Edge enhancement
  - Noise reduction
  - Dynamic range modification
- Potential to degrade displayed sharpness, detail

System Contrast Resolution/Detection

Determining Factors

- X-ray detector material, e.g. CsI
- X-ray tube capabilities
- System noise (vs. X-ray dose)
- Dynamic range
- Degradation processes
  - Scatter radiation
  - I.I. veiling glare
  - Image lag
- Image processing

Threshold Contrast Detail Detectability

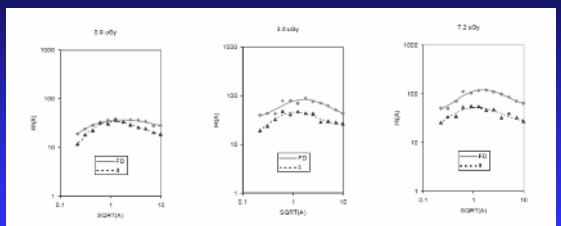


Figure 17: Results of observation tests FD versus II/TV 17 cm field size

Bruijns, SPIE 2002

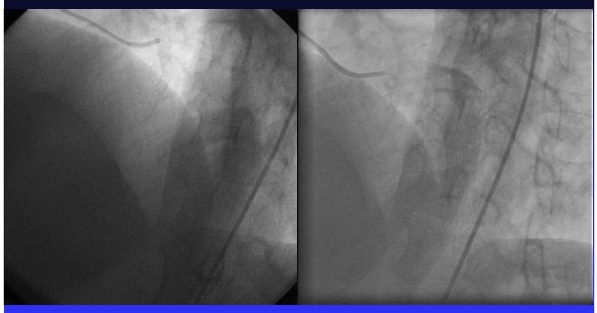
Flat Panel Imaging Systems

Image Processing

- Spatial frequency enhancement
- Noise reduction
- Contrast equalization
  - "Dynamic Range Reduction"
- Digital magnification
- Independent of specific detector
- Possible artifacts
  - Edge artifacts - "halo"
  - Contrast inhomogeneity
  - Blurr

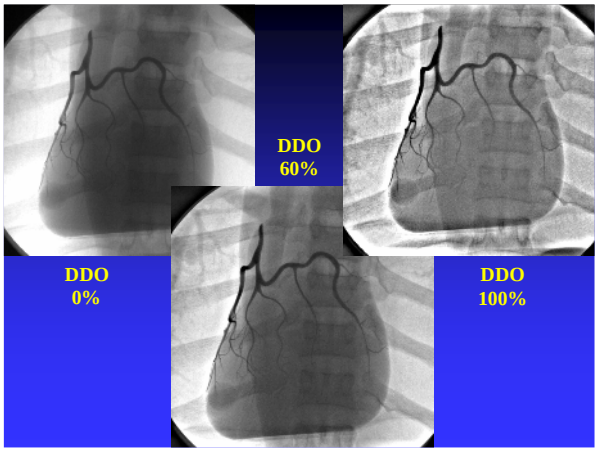
MAYO CLINIC

AAPM 08/02/2006



II/CCD vs. FPD, 4/05 vs. 9/05

70 yr old female, 63 kg



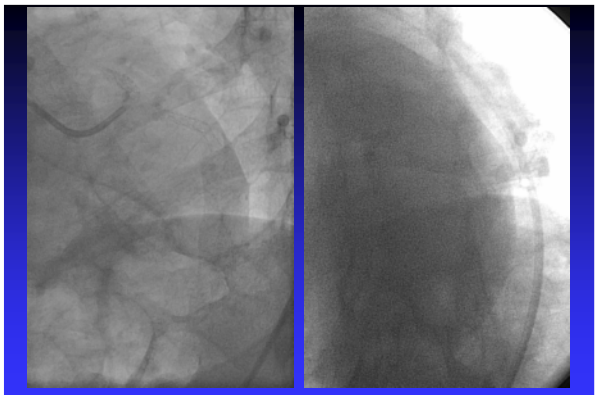


Image Processing - FPD vs. II/CCD

Function of Entire **System**

Flat Panel Imaging Systems

Image Processing (cont'd)

- Modifications?
  - Not all can be changed in post-processing
  - Must be set before acquisition
- Archived images
  - Limited choices
  - Third-party review systems
  - Degraded display
- Different algorithms interact

Flat Panel Imaging Systems

Fundamental Technical Advantages?

- "Improved DQE"
  - "Greater than I.I.'s
  - Reduce radiation exposure

Not that simple

DQE - Flat Panel vs. I.I.

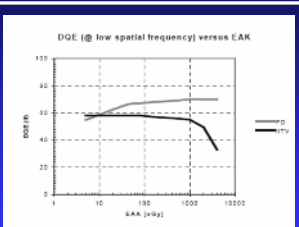


Figure 13: DQE(at low spatial frequency) versus EAK

Bruijns, SPIE 2002

DQE of Flat Panel Detectors

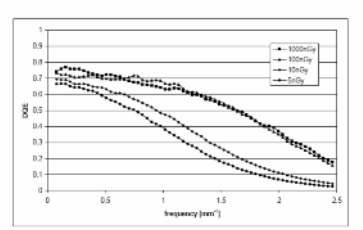


Figure 8. DQE curves for the flat panel detector at various dose levels.

Busse, SPIE 2001

DQE of Flat Panel Detectors

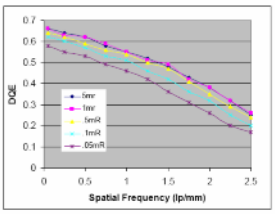


Figure 6: DQE as a function of Exposure level

Kump, SPIE 2001

Flat Panel Imaging Systems

- Radiation Exposure
  - Marketing claims vs. reality
- Determining Factors
  - Detector dose
  - X-ray tube capacity
  - X-ray spectral filtering
  - Image processing
  - System options

Radiation Exposure Reduction

- System Options
  - Spectral filtering
  - Radiation-off collimation
  - Radiation-free positioning
  - Stored gantry positions
  - Noise reduction image processing

Radiation Exposure Reduction

- Spectral Filtering
  - Copper - 0.1 to 0.9 mm
    - Potential for 10-70% reduction
    - Typically used in fluoroscopy
    - Effects on image quality?
  - Tube capacity
    - 3000 - 4000 W rating
  - Generator capacity
    - 1500 W limit?

Radiation Exposure Reduction

Image Processing Methods

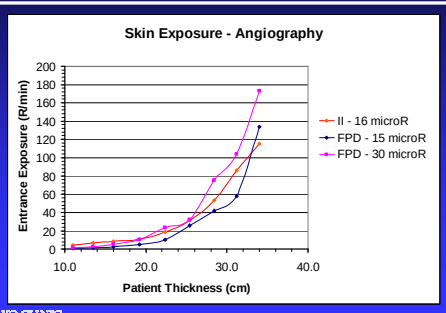
- Temporal filtering
  - Weighted sum of successive frames
  - Motion detection
- Potential for blurring
- Primarily in fluoroscopy
- Less common in record
- Interaction with other processing

Radiation Exposure

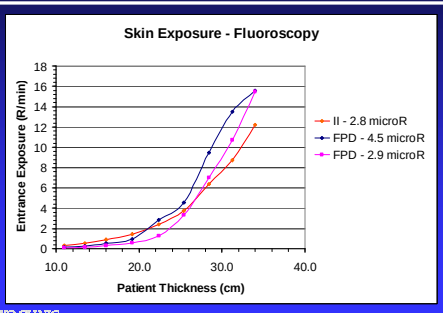
Detector Dose vs. Patient Exposure

- Role of spectral filtering
  - Can have 2-3X detector dose at same entrance exposure to the patient
  - Same detector dose with reduced entrance exposure
- Ask for specification
  - Site visits
- Most important for fluoroscopy

FPD vs. II - Angiography Exposure



FPD vs. II - Fluoroscopy Exposure



Interventional Imaging Systems

Feature Lag

- Biplane acquisition
- Large area detector
- Digital subtraction options
- Analytical software options

Not all Combinations!

Different timetables for each vendor

Interventional Imaging Systems

"State-of-the-art" Options

- Rotational Angiography
- 3-Dimensional Reconstruction
- Volume CT

System Requirements

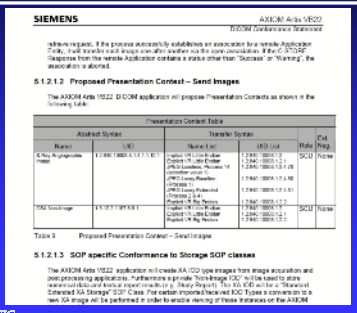
- Cost?
- On-line vs. Off-line?
- Additional Workstation?

Interventional Imaging Systems

Connectivity

- DICOM
  - Check conformance statement
  - Ask questions
    - Actual compatibility with Review/Storage network in use
  - Test connectivity
  - HIS/RIS
    - Modality Worklist
    - Modality Performed Procedure Step (MPPS)
  - Inbound

DICOM Conformance



SIEMENS AXIOM Artis VB22

DICOM Conformance Statement

retrieve request. If the process successfully establishes an association to a remote Application Entity, it will transfer each image one after another via the open association. If the C-STORE Response from the remote Application contains a status other than "Success" or "Warning", the association is aborted.

5.1.2.1.2 Proposed Presentation Context – Send Images

The AXIOM Artis VB22 DICOM application will propose Presentation Contexts as shown in the following table:

Presentation Context Table					
Abstract Syntax		Transfer Syntax		Ext. Neg.	
Name	UID	Name List	UID List	Role	
X-Ray Angiographic Image	1.2.840.10008.5.1.4.1.1.12.1	Explicit VR Little Endian Implicit VR Little Endian JPEG Baseline, Process 1 (default lossy) JPEG Lossy Baseline (Process 2 & 4) JPEG Lossy Extended (Process 3 & 5) Implicit VR Big Endian	1.2.840.10008.1.2 1.2.840.10008.1.2.1 1.2.840.10008.1.2.4.70 1.2.840.10008.1.2.4.50 1.2.840.10008.1.2.4.51 1.2.840.10008.1.2.2	SCU	None
DSA Sub-Image	1.2.840.10008.5.1.4.1.1.12.1.1	Explicit VR Little Endian Implicit VR Little Endian Implicit VR Big Endian	1.2.840.10008.1.2 1.2.840.10008.1.2.1 1.2.840.10008.1.2.2	SCU	None

Table 9 Proposed Presentation Context – Send Images

5.1.2.1.3 SOP specific Conformance to Storage SOP classes

The AXIOM Artis VB22 application will create XA IOD type images from image acquisition and post processing applications. Furthermore a private Time-Image IOD will be used to store measurements and textual report results (e.g. Study Report). The XA IOD will be a "Standard Extended XA Storage" SOP Class. For certain imported/received IOD Types a conversion to a new XA image will be performed in order to enable viewing of those instances on the AXIOM

DICOM Conformance

MAYO CLINIC

AAPM 08/02/2006

Digital Angiographic Data Requirements

Imaging Parameter	Cardiac Angiography	Vascular Angiography
Image Matrix	512^2 , 1024^2 x 8 bit	1024^2 x 10, 12 bit
Frame Size	0.25, 1.0 MB	2 MB
Field of View	15 – 22 cm	25 – 40 cm
Spatial Resolution	0.1 – 0.3 mm	0.25 – 0.4 mm
Acquisition Rate	30 – 60	2 – 7.5
Acquisition Rate (MB/sec)	7.5 – 60	4 - 15
Image Object Size	30 – 300 MB	2 MB
Image Objects/Exam	10	50 – 400
Acquired Data/Exam	300 – 3000 MB	100 – 800 MB
Exams/Day	6 – 8	4 – 6
Acquired Data/Day	1.8 – 24 GB	0.4 – 4.8 GB
Stored Data/Week	9 – 120 GB	0.5 – 12 GB
Stored Data/Year	450 – 6000 GB	25 – 600 GB

Interventional Imaging Systems

Data Requirements

- 1024 x 1024 Image Matrix
  - Large Area @2048 (2480x1960)
- 16 bit acquisition
  - 12 bits on disk
- Archive options
  - Downsize to 512 x 512?
  - Store as 8 bit?
  - Significant impact on review and storage

MAYO CLINIC

AAPM 08/02/2006

358 Frames: 512^2, 8 bit vs 1024^2, 16 bit

One sequence: 89.5 MB vs 716 MB (just AP)

Retrieval: 30 frames/sec vs. 3 frames/sec

Image Storage

- NAS RAID
- 5000 exams online
- 2000 DVD capacity
- Mutiple DVD drives
- 70,000 exam archive

Ten years storage

(before flat panels)

Image Storage

- NAS RAID
- 5000 exams online
- 2000 DVD capacity
- Mutiple DVD drives
- 70,000 exam archive

1.3 years storage!!

Review at 1-3 frames/sec

Increased network demands

Interventional Imaging Systems

Summary

- FPD vs. I.I. - Is there still a choice?
- FPD is an important technological development in digital imaging - no going back.
- Image quality is affected by multiple factors in addition to the detector.
- Significant advantages also provided by associated technical improvements.

Interventional Imaging Systems

Summary (Continued)

- We need to match clinical requirements and expectations.
- There is no revolution in physics.
  - Not a miracle cure for "bad fluoro"
  - Better images still require more x-rays
- Compromise is a fact of life
  - Advantages vs. disadvantages