Configuration of Fluoroscopes General or Interventional for Pediatric Procedures

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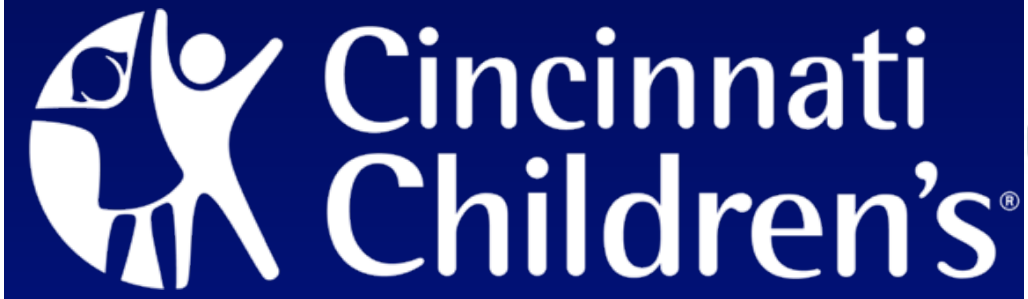


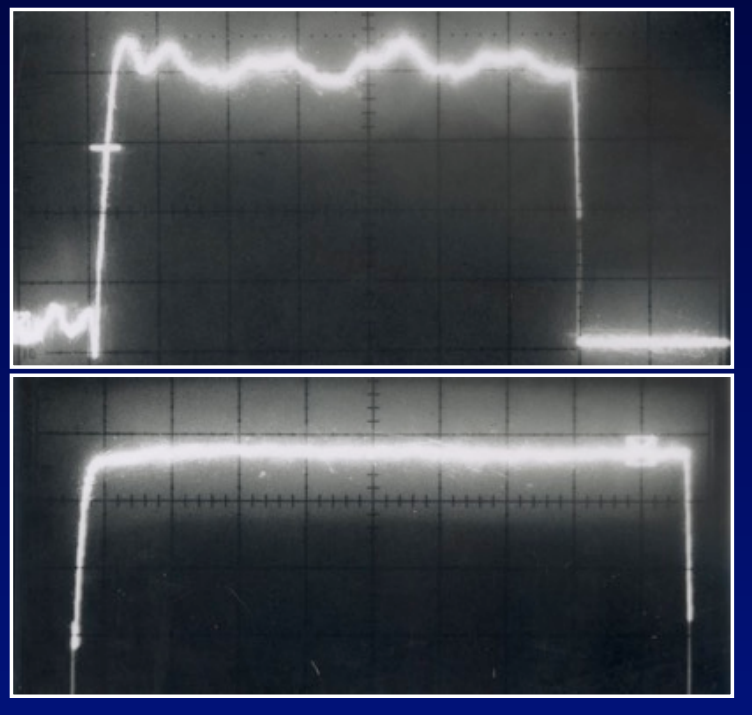
Introduction

- Impact of new **Paradigms** for fluoroscope management by the medical physicist.
- Unique challenges of **pediatric fluoroscopy**
- Staff training
- Assessment of newer features
- Configuration Consideration: Modified Techniques

New Paradigms Impacting Management of Annual Testing of Fluoroscopes

1. More accurate control of acquisition parameters by state-of-the-art fluoroscopes:

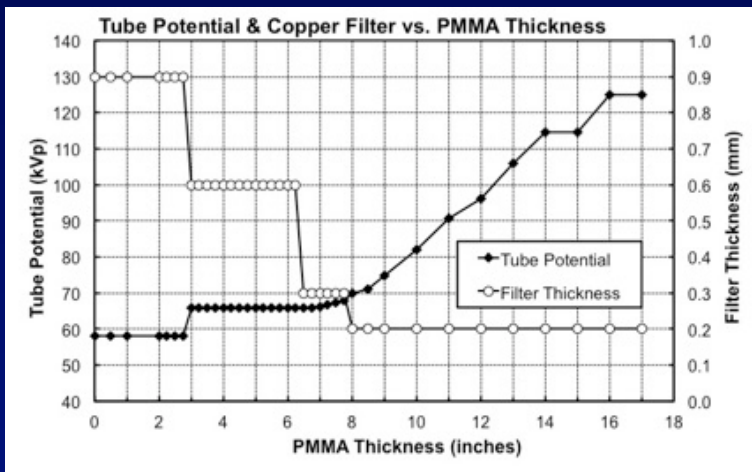
- Improves consistency and reliability of performance
- Accuracy of acquisition parameters can be spot checked to reduce room down time for annual compliance testing

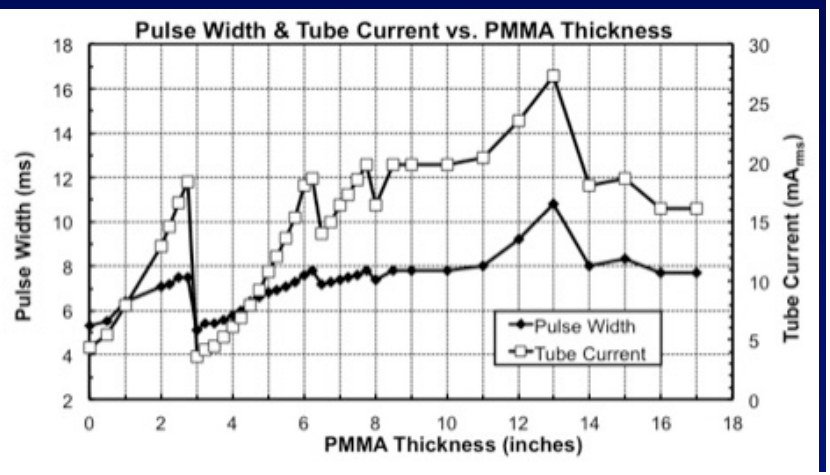


New Paradigms Impacting Management of Annual Testing of Fluoroscopes

2. Expanded variety and complexity of **operational acquisition modes** :

- Fluoroscope's design strengths must be **configured** for each **unique** practice
- Equipment manufacturer needs assistance



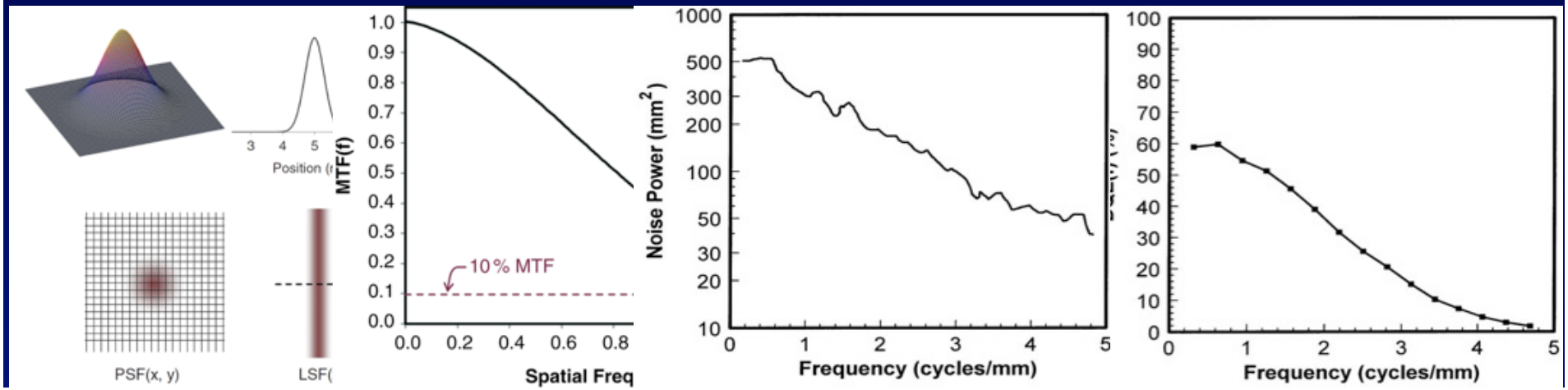


AAPM
TG 125

New Paradigms Impacting Management of Annual Testing of Fluoroscopes

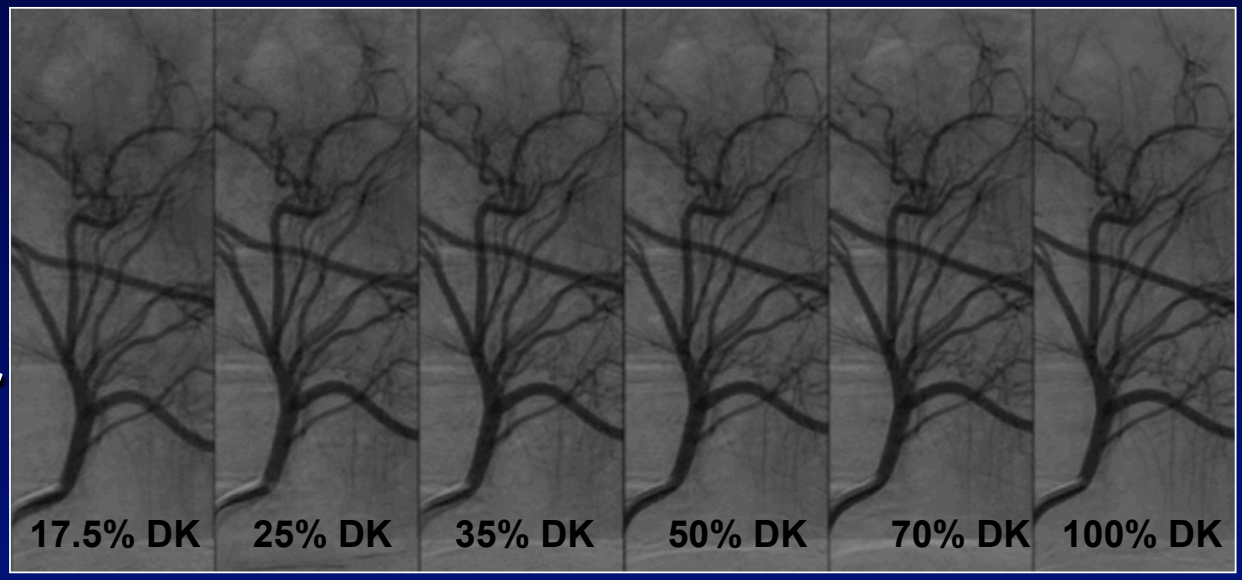
3. Large variety of images require quality monitoring:
   - **Quantitative analysis** of HCR, LCR, & TRC

     High & Low Contrast Resolution & Temporal Resolving Capability with **simpler** phantoms

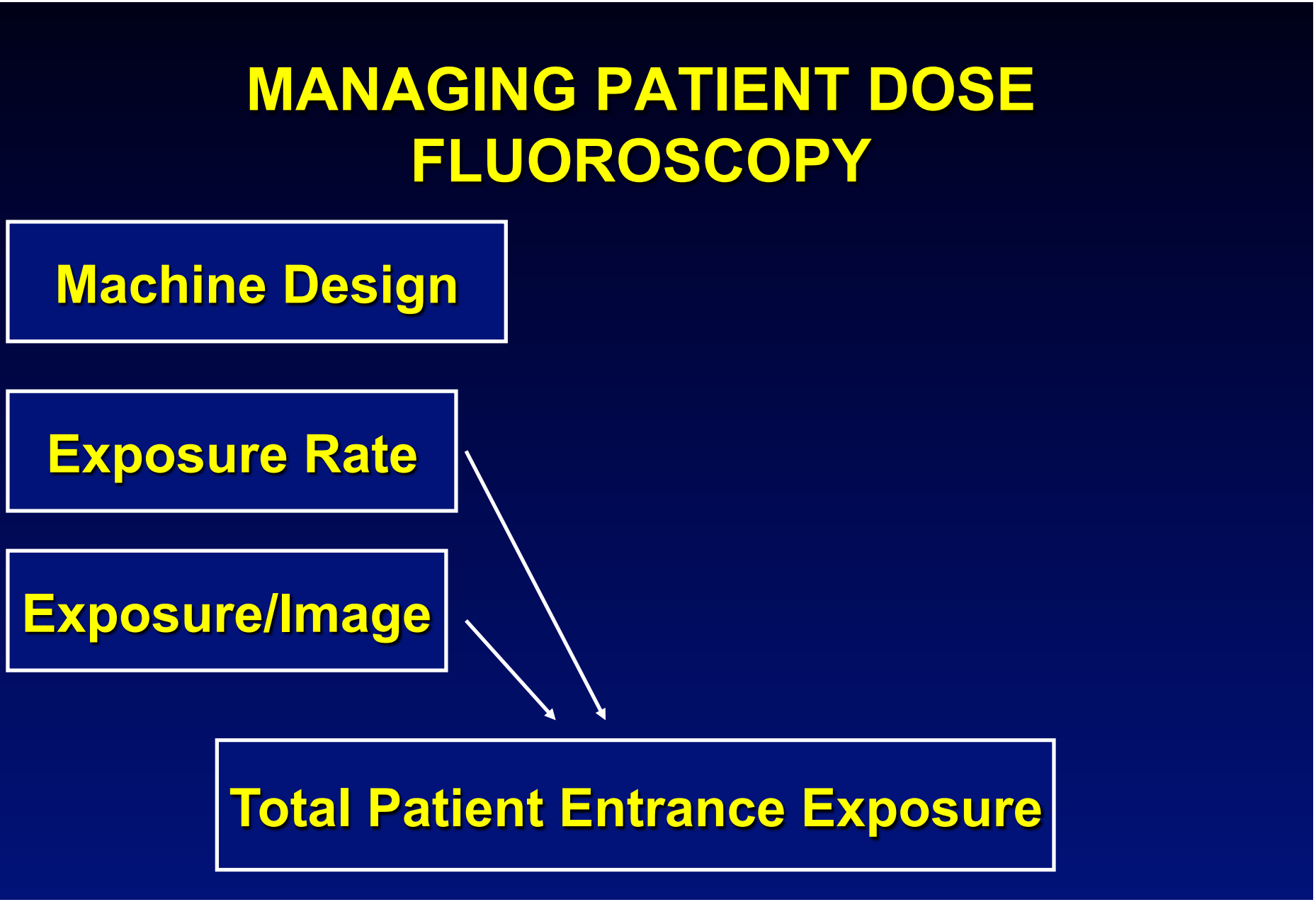


New Paradigms Impacting Management of Annual Testing of Fluoroscopes

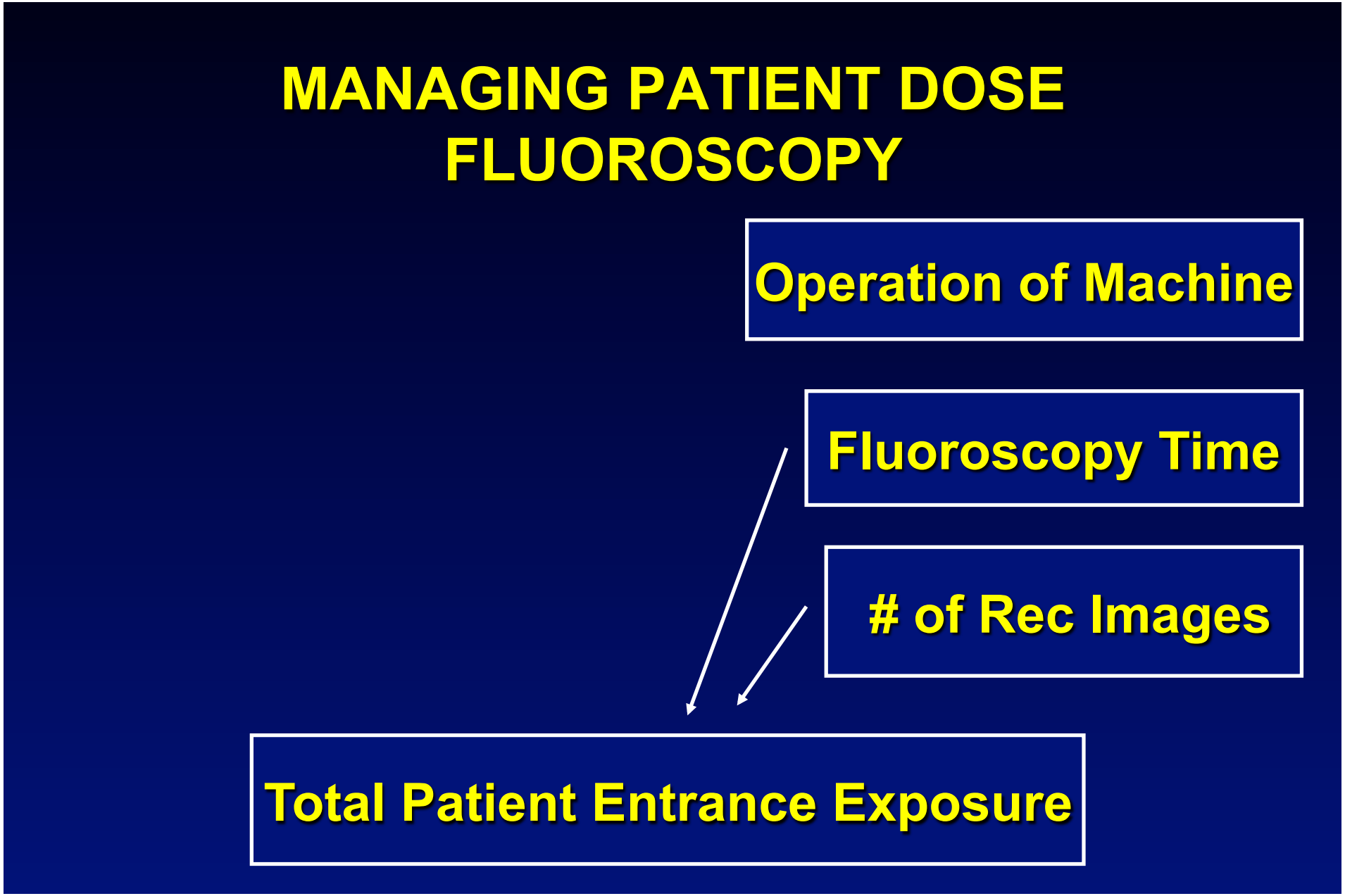
4. Image quality of some state-of-the-art fluoroscopes is better than clinical requirements:
   - Opportunity to reduce patient dose
   - Foreign concept to equipment manufacturer

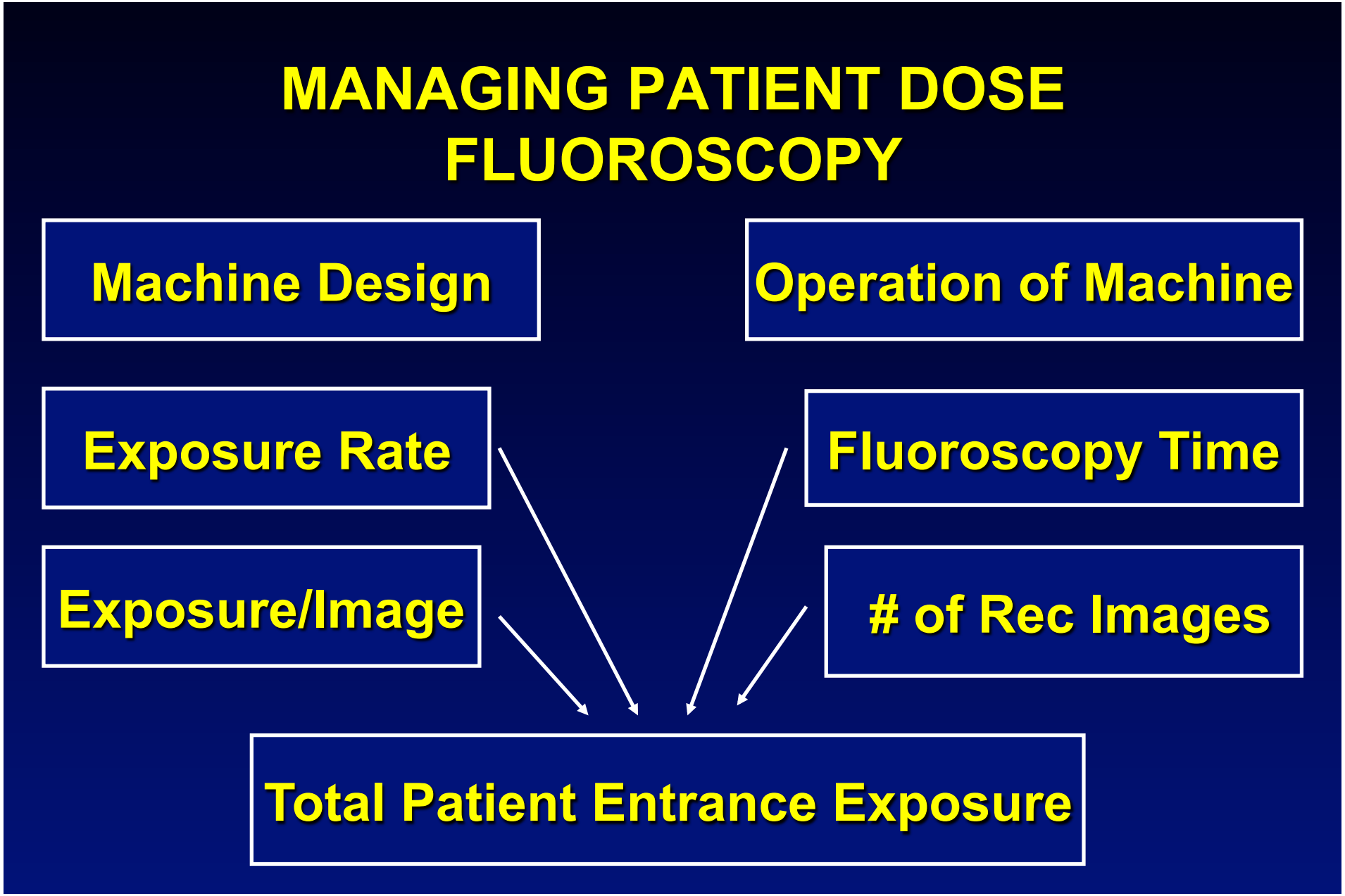


MANAGING PATIENT DOSE FLUOROSCOPY



MANAGING PATIENT DOSE FLUOROSCOPY



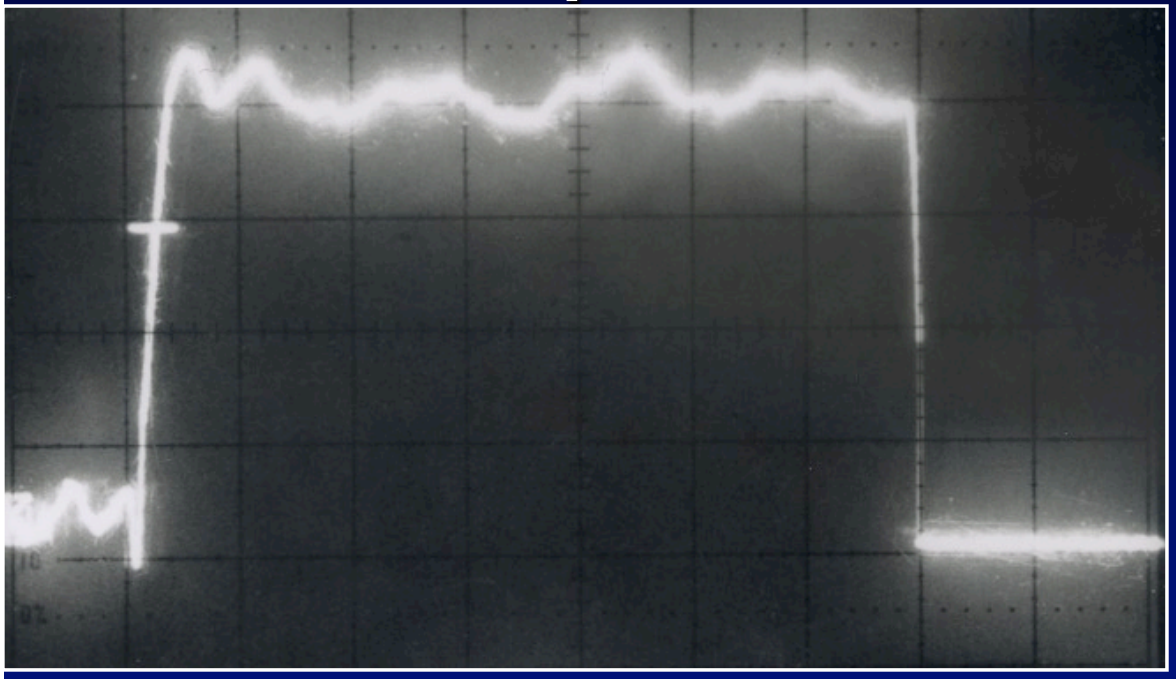

MANAGING PATIENT DOSE
FLUOROSCOPY
Machine Design
Operation of Machine
Exposure Rate
Fluoroscopy Time
Exposure/Image
# of Rec Images
Total Patient Entrance Exposure

Old Philosophy

Compliance Testing Era: 1975 – 2015

- Equipment used **open loop control logic**

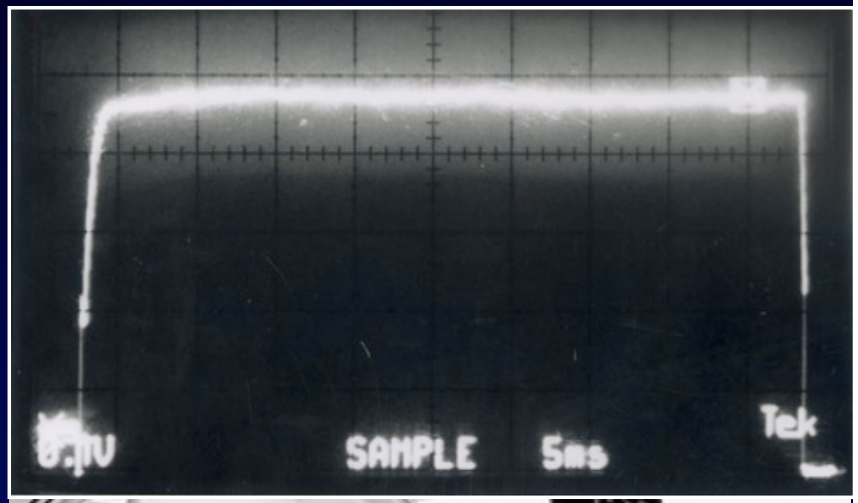
80 kVp waveform



Diagnostic Angio ~ 1975

Configuration/Operations

- **Image quality requirements function of:**
  - **Exam type**
  - **Patient Size**
- **Operational parameters**
  - **Focal spot size**
  - **Pulse rate**
  - **Pulse width**
  - **Added Beam Filtration**
  - **Detector air Kerma levels**
  - **Accuracy of dose displays**
  - **Unique image processing**



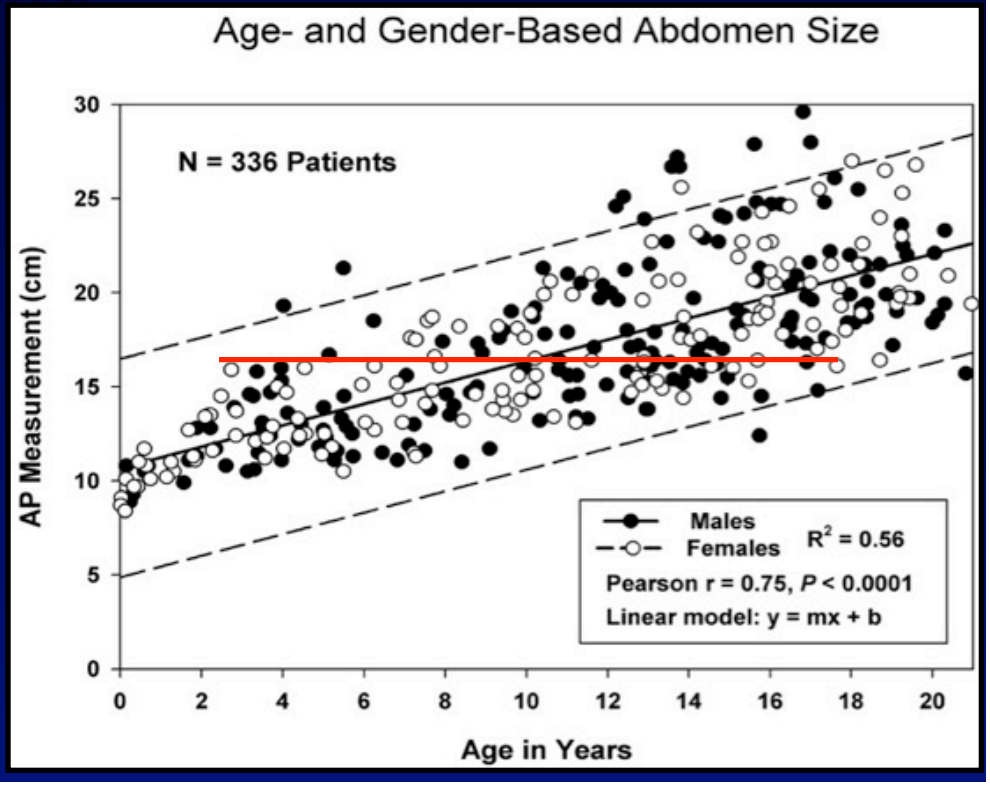
AGE vs PATENT SIZE?

Same age patients vary dramatically in size.

- **Abdomens of:**
  - **Largest 3 year olds and**
  - **Smallest adults are**

  the same size.

- **Patient cross sectional thickness, not age, should be used.**



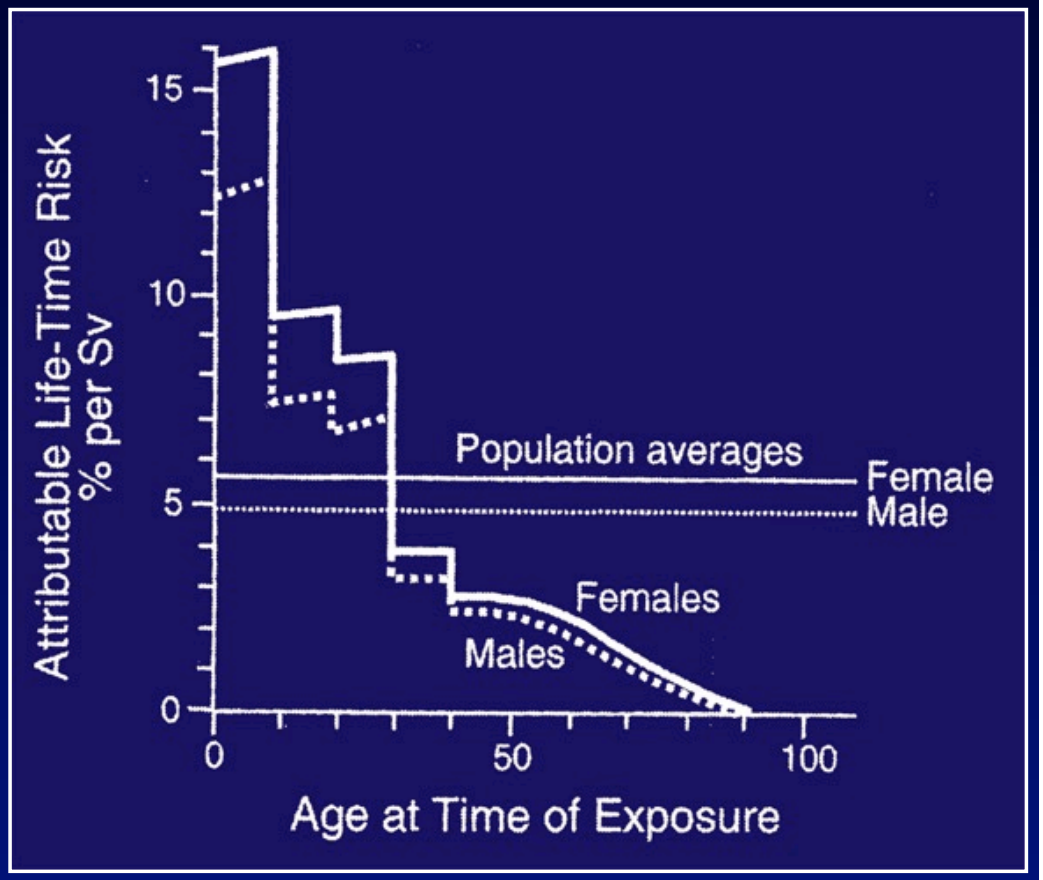
Patient Size

Patient Size

PEDIATRIC IMAGING CHALLENGES

3. Stochastic Sensitivity of Patient to Radiation

- **Radiation Induced Cancer Lifetime Risk From 1 Sv Whole Body Dose**
  - 1st Decade: 15%
  - 2nd Decade: 8%
  - All Ages: 5%
  - Middle Age: 2%
  - **Child 3 - 5 times More Sensitive**



Hall

PEDIATRIC IMAGING CHALLENGES

4. Clinical Problems of Children are Complex

- Congenital Heart Defects and/or Diseases
  - "Black Box"
  - 4 - 8 hr Exam Times
- Malformations in Anatomy Corrected in Stages
  - Up to 10 catheterizations before 21st birthday
  - Multiple interventions over weeks

PEDIATRIC IMAGING CHALLENGES

5. Image Quality Concerns

- **Small Anatomical Size**
  - **Improve** High Contrast Resolution
    - Image Processing: **Edge Enhancement**
    - **Increase Matrix Size** of Digital Image
    - **Limited Subject Contrast**
  - Calcium in Skeleton limited
  - Neonate < 20%
  - Adult ~ 20%

TRAINING OF STAFF

Comprehensive Training Fosters

- Full Utilization of Equipment Design
- Optimum
  - Image
  - Quality
- Reduced Radiation Dose

TRAINING OF STAFF

- Types of Training
  - Core Knowledge Provided at Regular In-Services
    - Imaging Principles
    - Quality Control
    - Equipment Care
  - Radiation Protection Principles

- All should result in credentialing tied into the facility's granting of privileges to physicians

TRAINING OF STAFF

Types of Training

- "Buttonology": Unique Operational Features of Imaging Equipment
  - Didactic lecture followed by 'hands on' training
    - Application specialist of vendor may be of limited help if you have developed pediatric configurations
    - Phantom imaging on site
    - Relaxed schedule for first patients

Training of Staff

Training and Communication

- Do operators and staff know how to manage fluoroscopic imaging and dose?
- Do they understand the 'buttonology' of each fluoroscope in department?
- Are they comfortable with the largest bariatric patient, smallest pediatric patient and everyone in between?
  - http://asrt.mycrowdwisdom.com/diweb/catalog/item/id/170885/q/q=*22image*20gently*22&c=40
  - On ASRT & IG Website written by Image Gently for pediatric fluoroscopy

Assessment of Newer Features

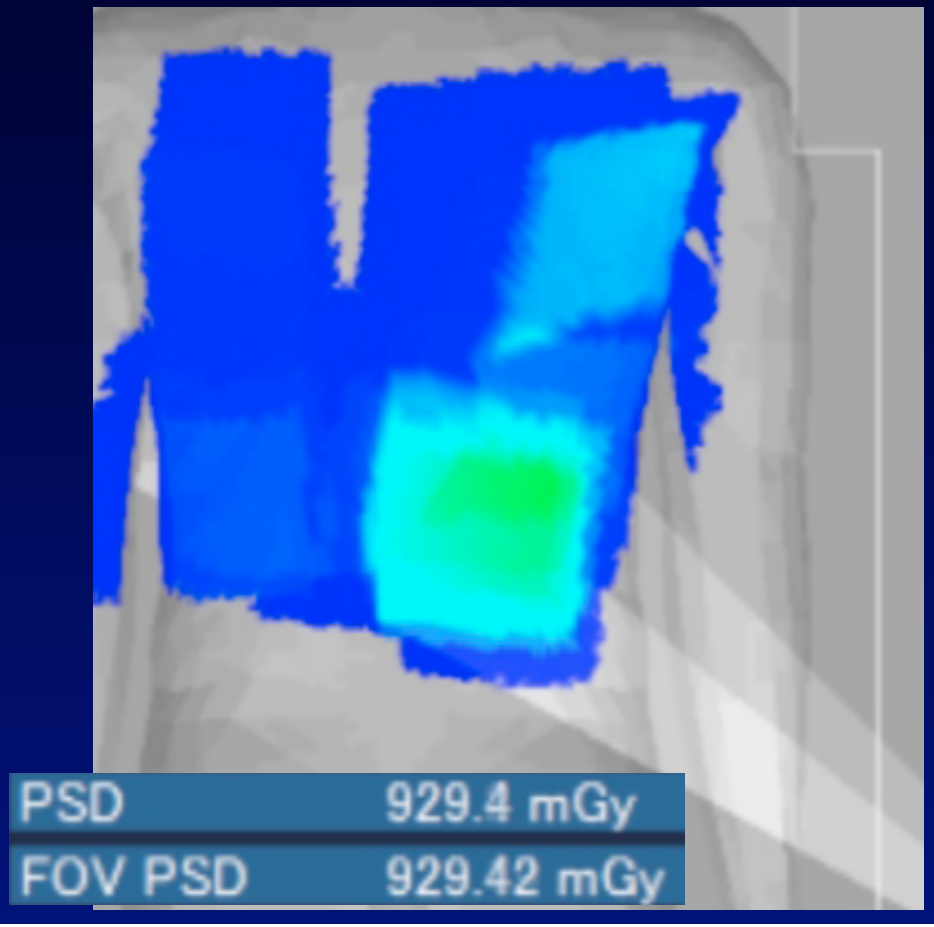
Display of AK at IRP or KAP

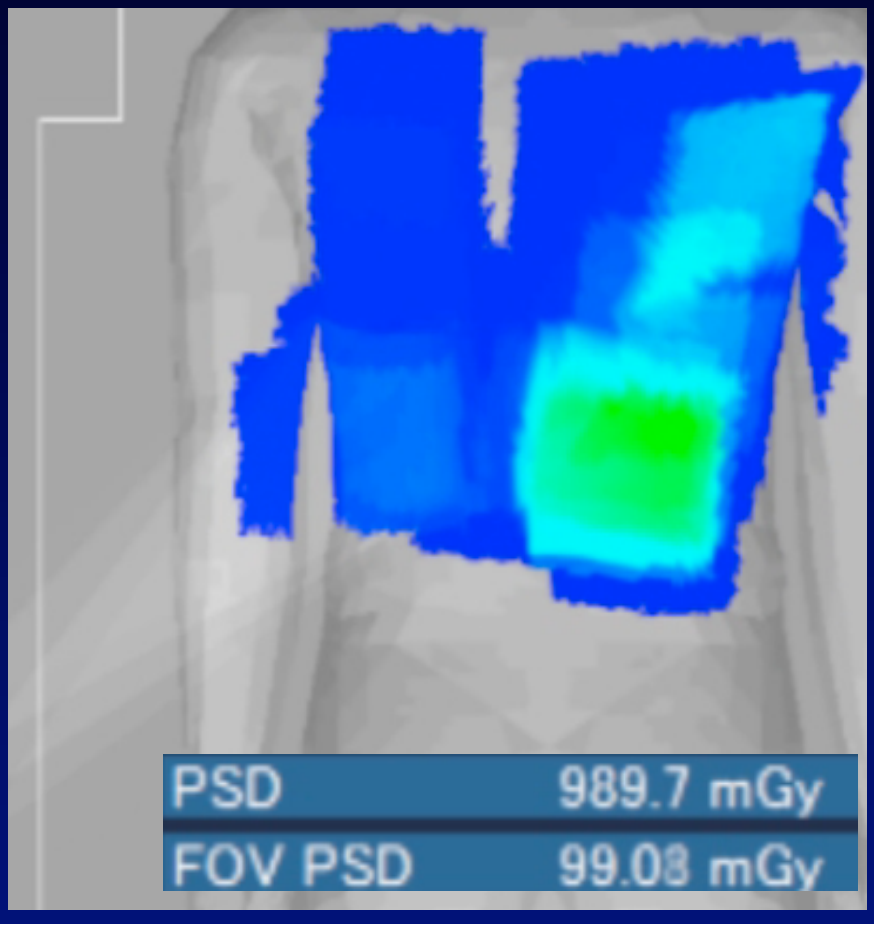
- AK: air Kerma: mGy
- KAP: Kerma-area-product: Gym^2, $\mu Gymm^2$, 10 $mGycm^2$
- IRP: interventional reference point

  15 cm toward focal spot from iso-center: 60 – 65 cm
- Required accuracy of display: $\pm$ 35%
  - Not a reproducibility problem
  - Measure calibration factor to apply to displayed dose index using guidance of AAPM TG 190
    - Quotable error of $\pm$ 10%

Assessment of Newer Features

Display of Peak Skin Dose





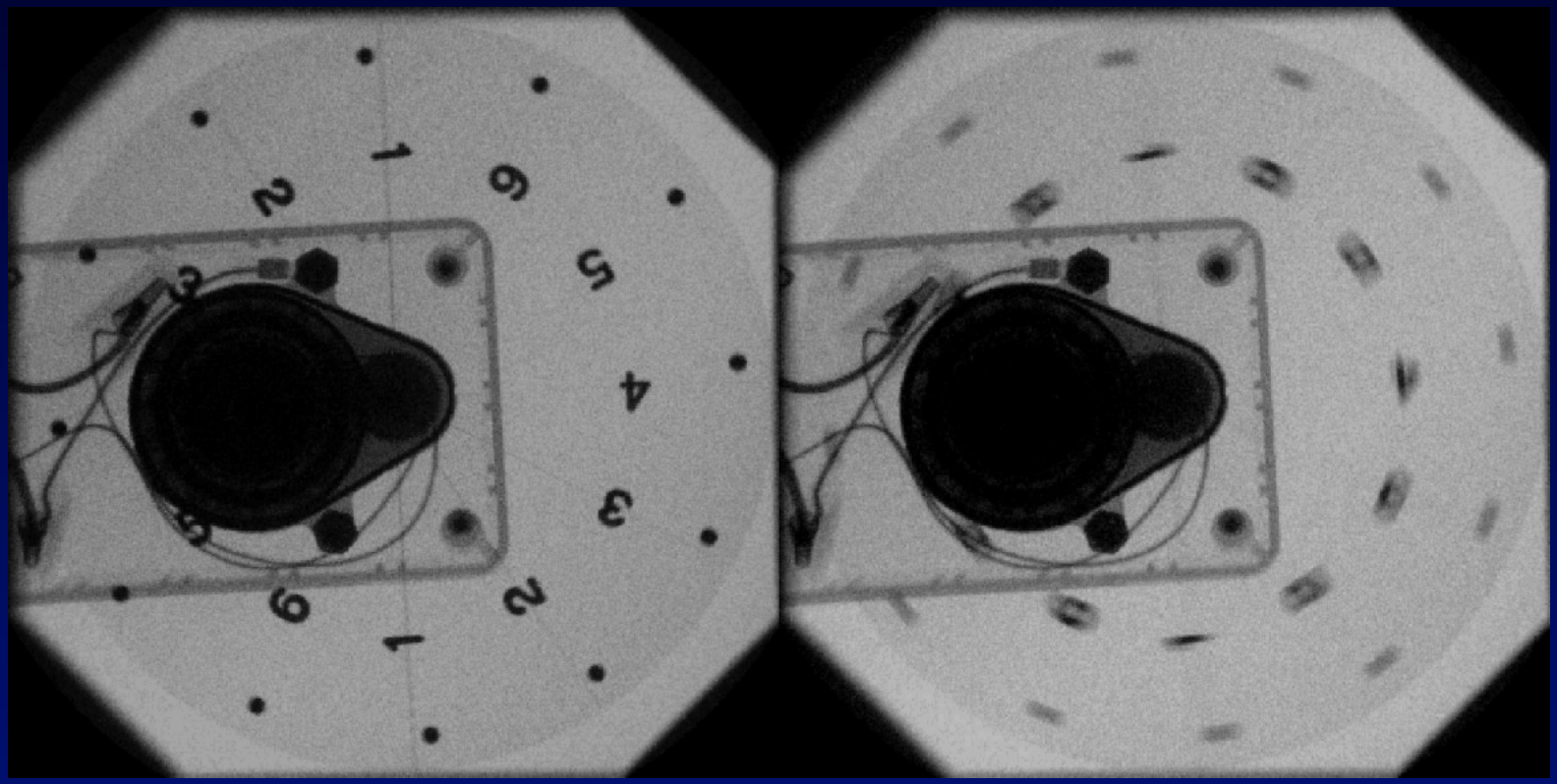
Assessment of Newer Features

Debate on Grid Removal for children

- **Remove grid** to reduce dose rate; accept image quality loss
  - Patient dose/image reduced 26%
  - Image quality reduced 26%
- **Do not remove grid;** reduce air Kerma rate to image receptor to achieve patient dose reduction/image
  - Only DSA mode evaluated with animal model
    - Accepted for publication in JACMP: Strauss KJ et. Al.

Configuration Considerations

Help your site's that are still in the 20th Century!



Pulsed Fluoro - 30pps
(Displayed at 7.5 fps)

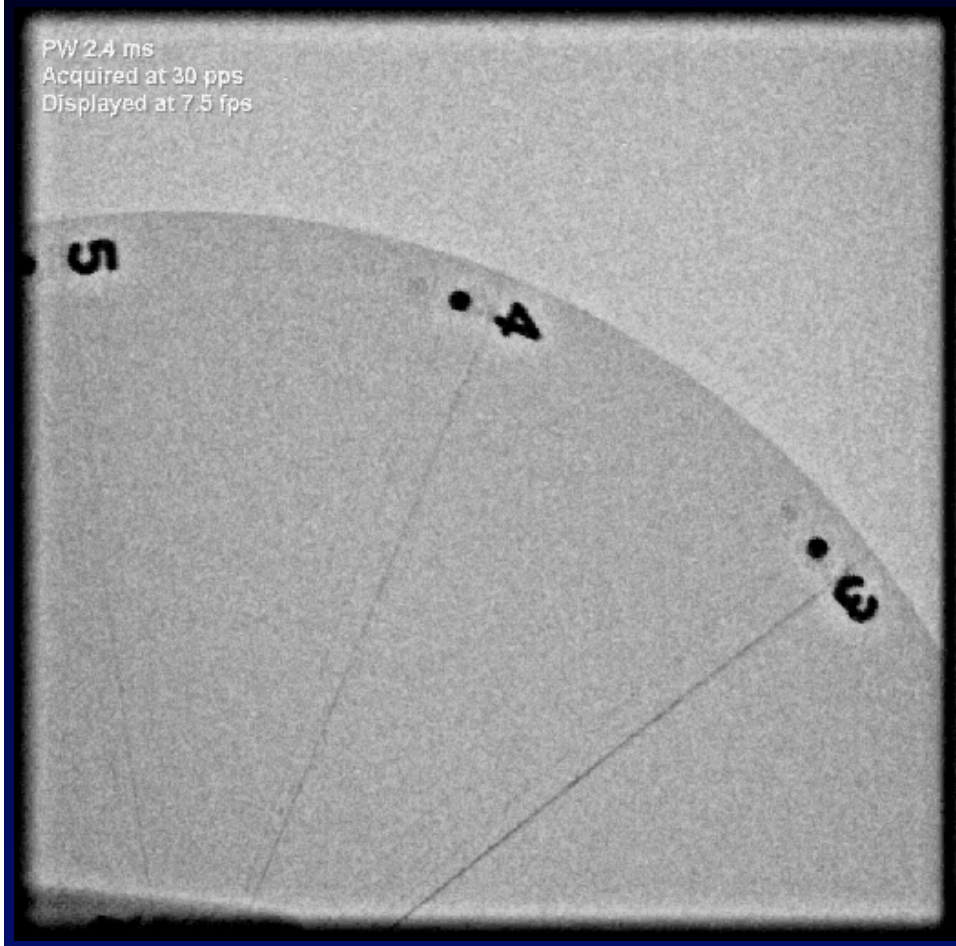
Continuous Fluoro
(Displayed at 7.5 fps)

Configuration Considerations
Technique Optimization

Improvement of acquisition configurations can happen **NOW!**

- **Freeze Patient Motion With Pulsed Fluoroscopy of appropriate pulse widths**
  - Pediatrics: 1 - 5 msec
  - Adults: 3 - 10 msec
  - Bariatrics: 7 - 15 msec

AFFECT OF PULSE WIDTH



PW 2.4 ms
Displayed 7.5 fps

PW 7.4 ms
Displayed 7.5 fps

Configuration Considerations
Technique Optimization

Other important acquisition parameters as a function of patient path length

- Focal spot size:
- Voltage & added filter:

  patient / image receptor dose
- Tube current:
- Pulse Width:
- Pulse rate:

Configuration Considerations
Technique Optimization

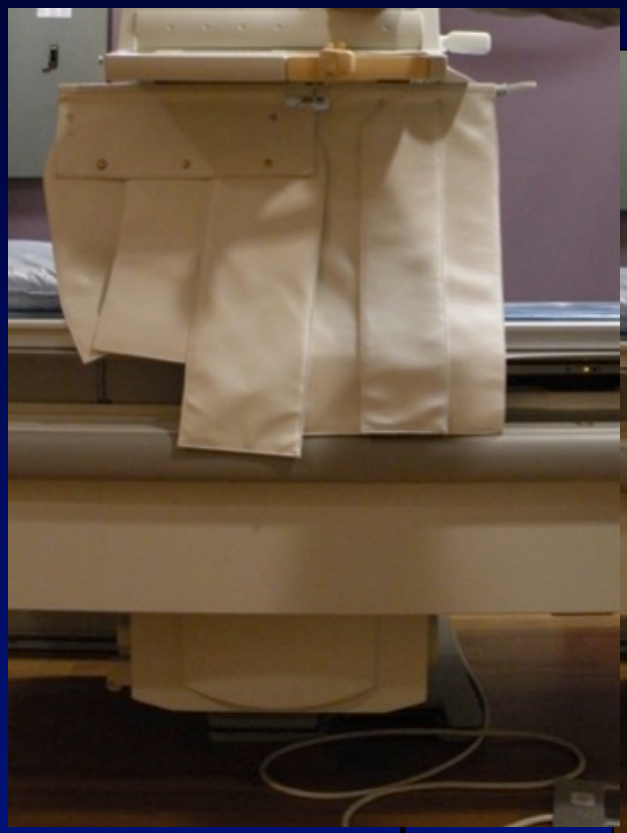
Pulse Rates (pulses/second)

Video Swallowing	**20**	15	10
Esophagram, UGI	15	**4**	2
Chest/Diaphragm	8	**4**	1
G-J Tube	4	2	**1**
All others[1]	4	**2**	1

[1]UGI/SBFT, small bowel, contrast enema, colostogram, Fistulagram, VCUG, nephrostogram, cloacagram, cystogram, G-J tube

Configuration Considerations Technique Optimization

- **Tube Lift**
  - Up: Source to Skin Distance 51 cm
  - Down: Source to Skin Distance 65 cm
    - 38% less patient dose

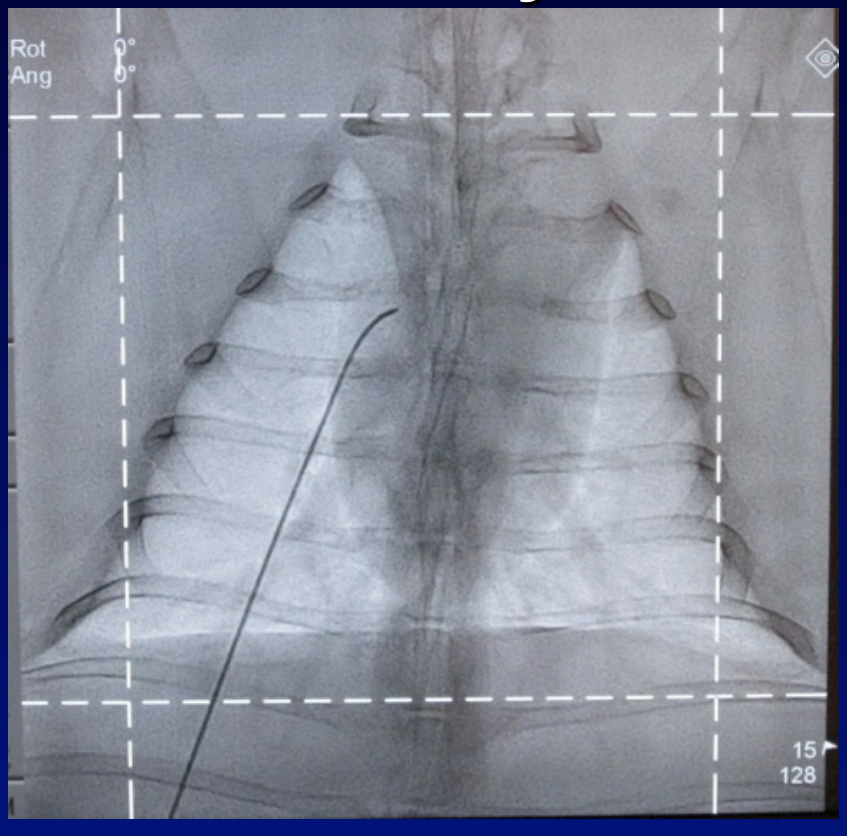


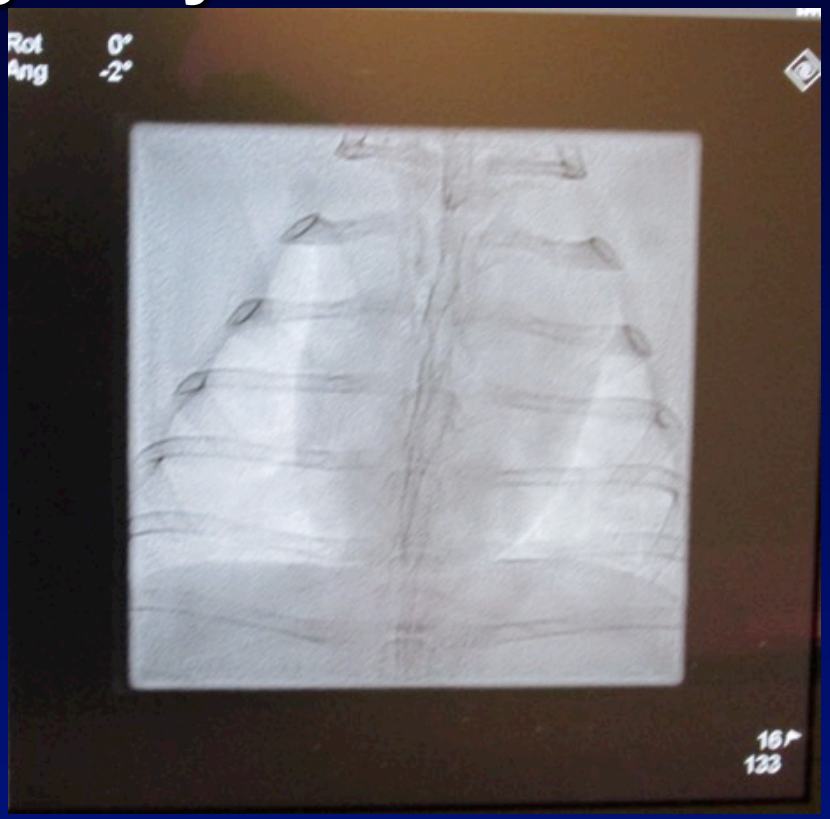
Configuration Considerations
Technique Optimization

- **Fluoro Image Grab**
  - Fluoroscopic image is stored on system disc at operator's request
    - Dose of fluoroscopic frame ~ 10% of acquired image
    - Substitute fluoroscopic images for fluoro-grahic images when fluoroscopic image is adequate.

Configuration Considerations
Technique Optimization

- **Virtual Collimation** removes all arguments for not manually collimating x-ray beam area!



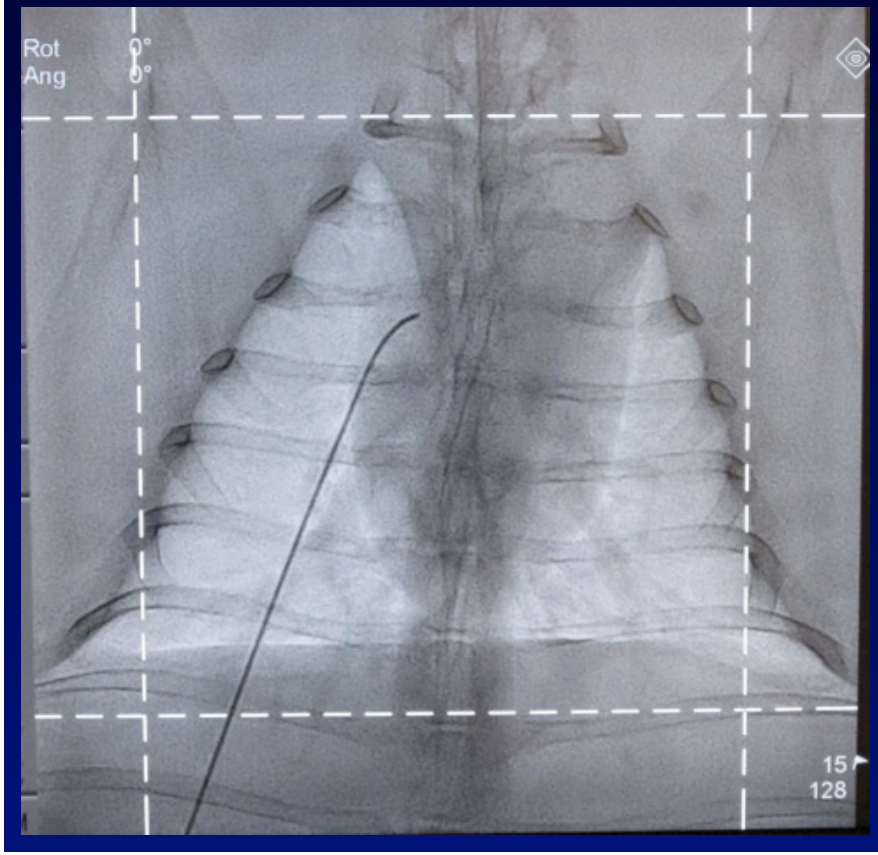


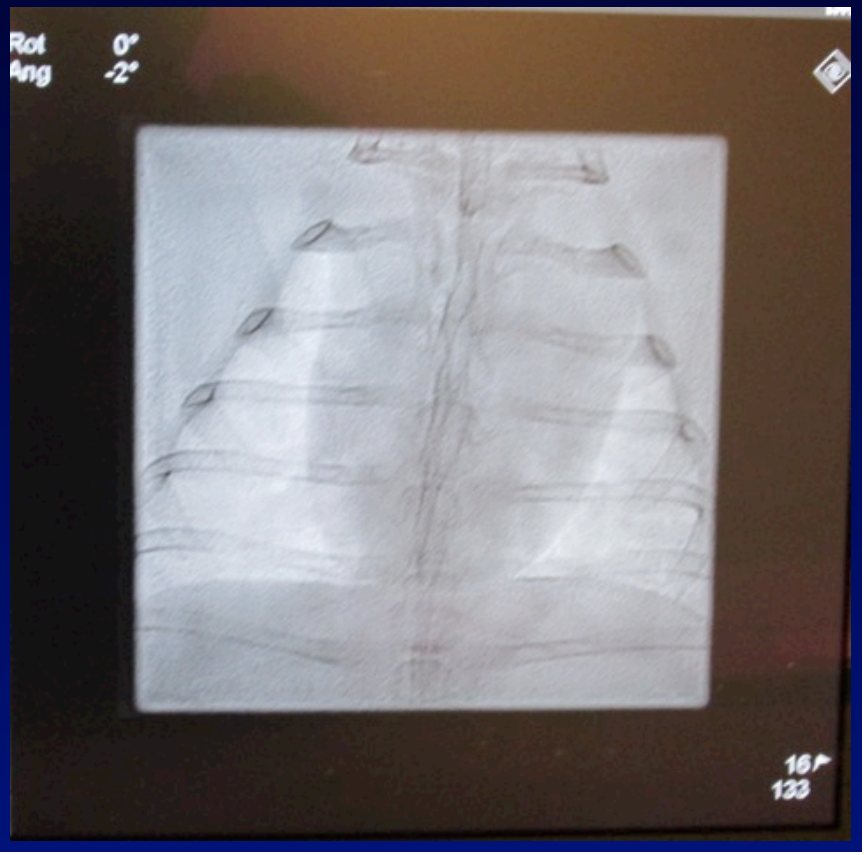
Configuration Considerations
Technique Optimization

- **Collimation with same FoV reduces patient *risk* more than only selecting a smaller FoV**
  - ***Risk* from ionizing radiation α radiation dose * mass of tissue irradiated**
    - **Halving the area of the x-ray field or halving radiation dose rate has a similar biological benefit.**

Configuration Considerations
Technique Optimization

- Halving x-ray field area maybe doable!





Summary of Potential Dose Savings

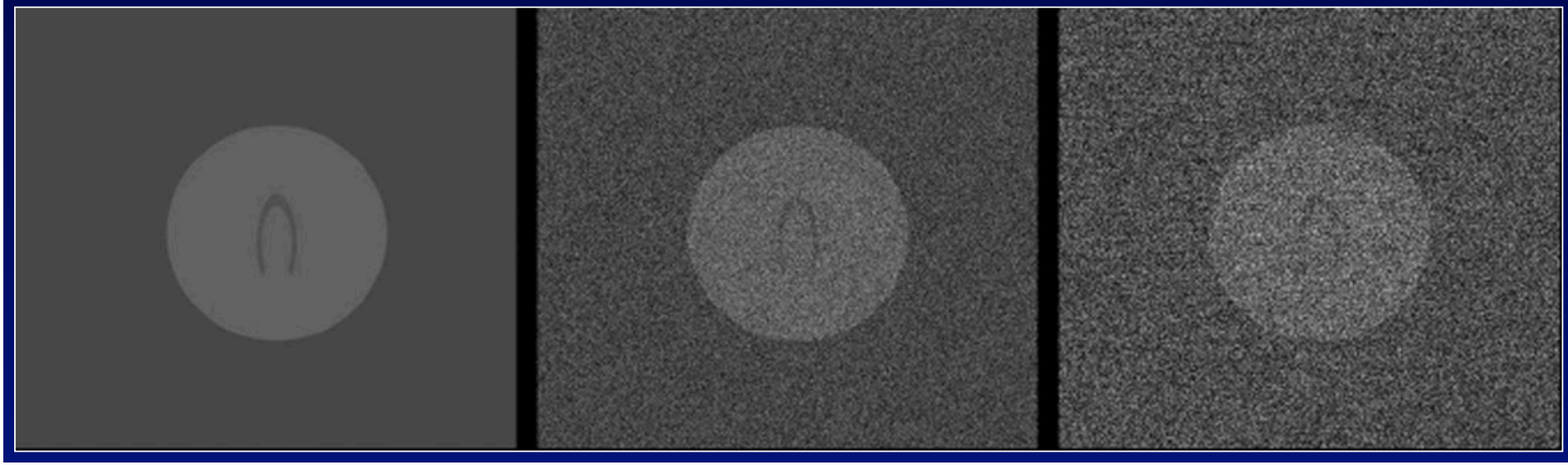
Step	New Dose/Old Dose
kV, mA, msec vs patient size	50%
Detector Dose Setting	± 50%
Pulse Rate vs Continuous	13%
Grid Removal	70%
Tube Lift	62%
Fluoro Grab vs Recorded Image	10%
31 vs 17 cm Field of View	55%
Tighter Collimation	100%
Avoid Gel Pad Post Patient	70%

Configuration Considerations: AKRIR

Air Kerma Rate At Image Receptor (AKRIR)

- Need sufficient photon flux to manage quantum mottle for Normal Mode
  - Typically: 2 x Low ~ Normal ~ 0.5 x High
  - Dependent on type of study

Archer & Wagner



Configuration Considerations: AKRIR

Pulsed fluoroscopy reduces patient dose rate? T or F

Constant AKRIR per image during Variable Rate Pulsed Fluoroscopy increases perceived noise with Pulse Rate Reduction.

- Low pulse rates during fluoroscopy are rejected more due to increased perceived noise in the images as opposed to loss of Temporal Resolution

Configuration Considerations: AKRIR

Increase AK per image as pulse rate during Pulsed Fluoroscopy decreases.

- AKIR/image relative to 30 p/s
  - AKIR / Frame α $(30/\text{Pulse Rate})^{1/2}$
    - Less frame integration by eye
    - Increase AKIR / Frame as pulse rate decreases

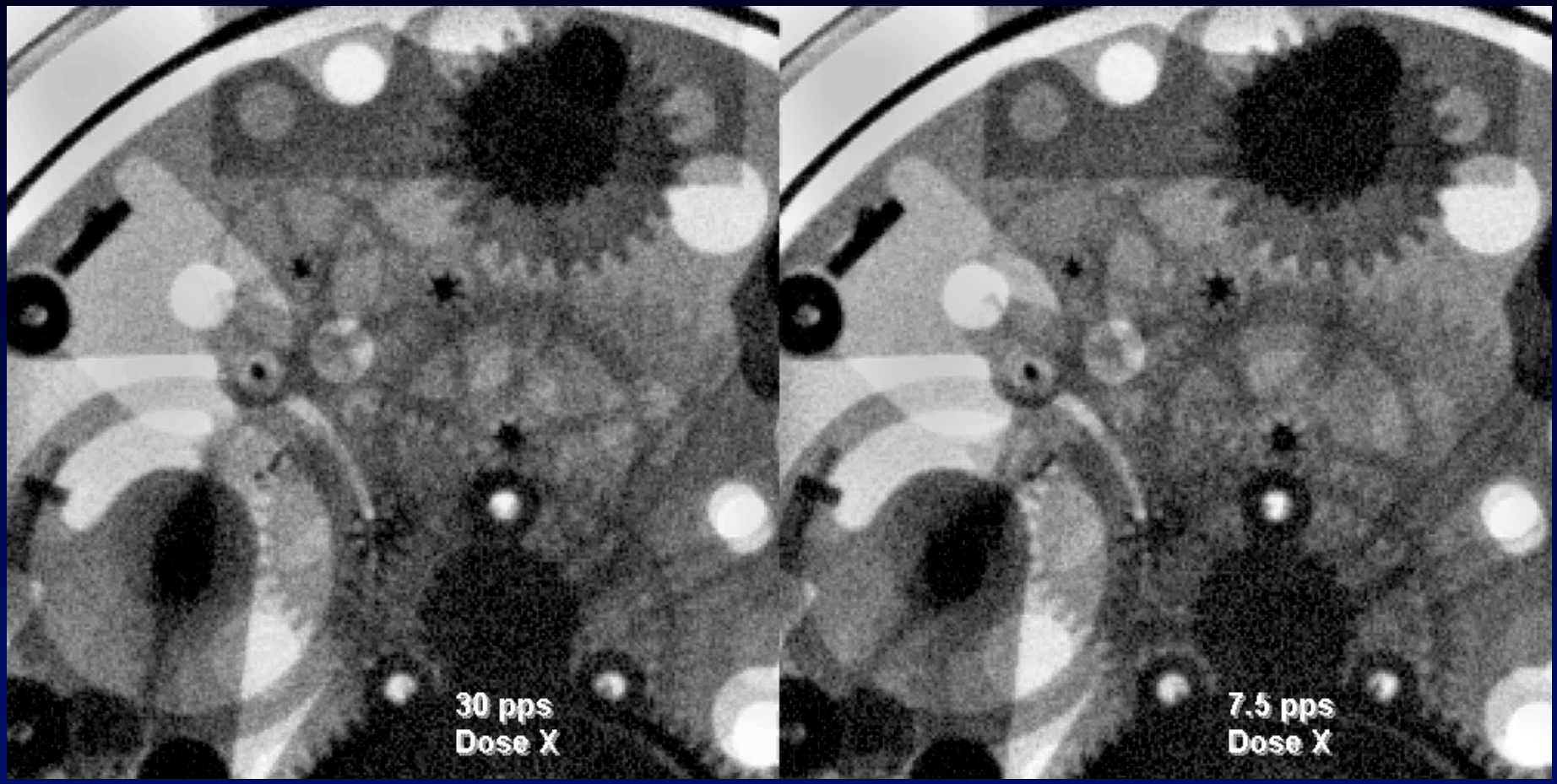
Aufrichtig R, et. al. Perceptual comparison of pulsed and continuous fluoroscopy. Med Phys 1994 21(2): p 246 – 56.

PERCIEVED NOISE PHANTOM

Uniform Background
Perceived Noise

Images courtesy of Phil Rauch

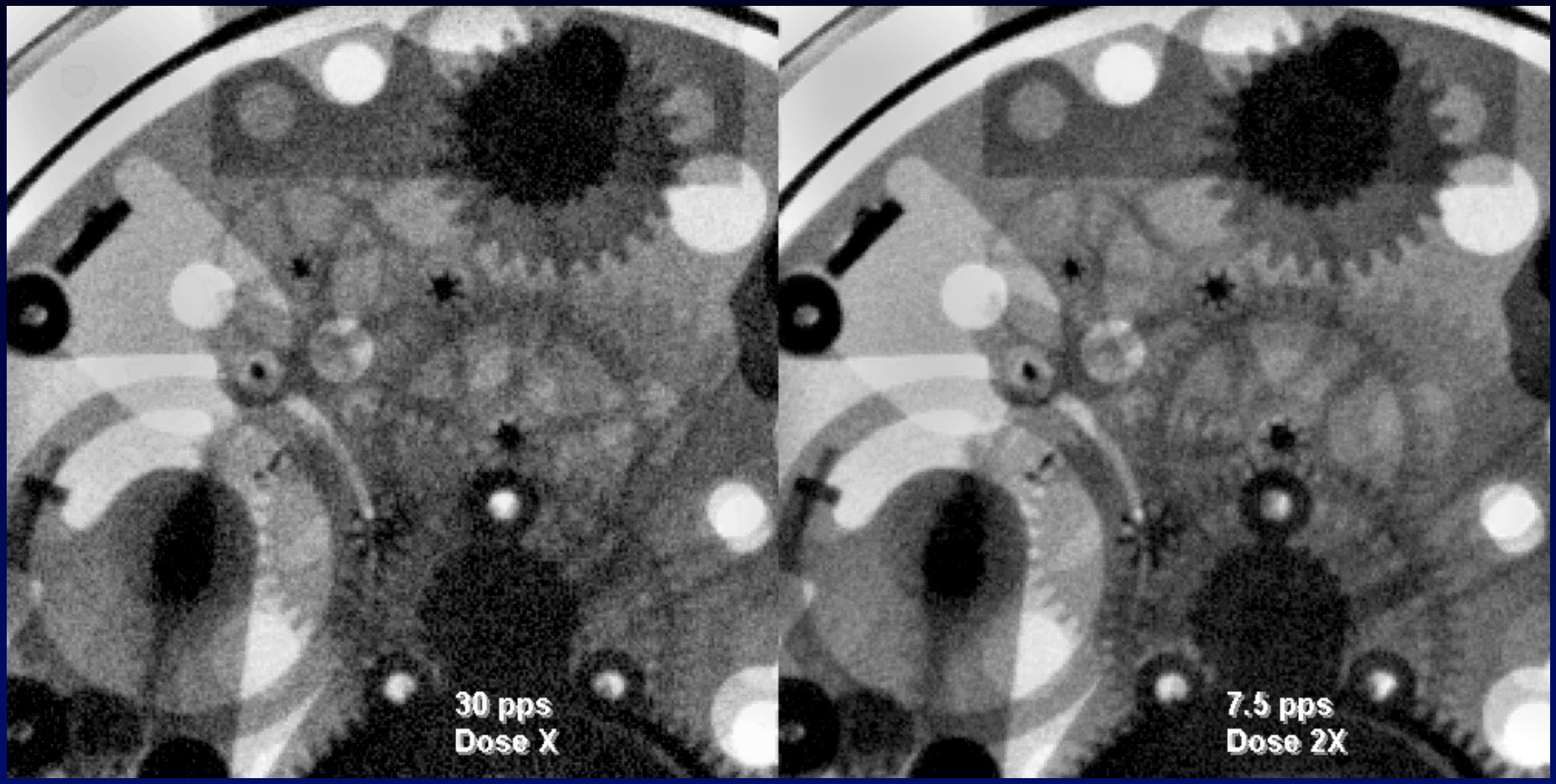
AUFRICHTIG PRINCIPLE



IR Exp/frame = X **Patient Exp Rate Reduced 4X**

Images courtesy of Phil Rauch

AUFRICHTIG PRINCIPLE



IR Exp/frame = X vs 2X Patient Exp Rate Reduced 2X

Images courtesy of Phil Rauch

Configuration Considerations: AKRIR

During Variable Rate Pulsed Fluoroscopy

- Exposures Relative to "Normal": 30 – 7.5 p/s
  - AKIR / Frame α $(30/\text{Pulse Rate})^{1/2}$

- AKIR / Frame < 7.5 pulses/second
  - AKIR / Frame α Constant

Configuration Considerations: AKRIR

Spectral Beam Filtering (z > 11 for added beam filtration) requires more AKRIR than std filtration

- Increases effective energy of x-ray beam
- Less photons @ same AKRIR
- Quantum Mottle increases

- **Double AKRIR rate wrt Standard Filtration**

Rauch P, et. al. AAPM TG125. Med Phys, 2012 39(5) pp 2826 – 8.

Configuration Considerations: AKRIR

- **AKRIR changes as a function of the selected Field of View (FoV)**
  - Image Intensifier/Fixed aperture: AKRIR α 1 / FoV^2
  - Image Intensifier/Adj aperture: AKRIR α 1 / FoV
  - Flat Panel Detectors:
    - Small area (unchanged binning): AKRIR α 1 / $FoV^{0.5}$
      - Reducing FoV in half increases AKRIR 40%
    - Large area: AKRIR α 1 / FoV when binning changes
      α 1 / $FoV^{0.5}$ no binning change

Conclusions

- Physics testing should become an operational resource
- Quantitative, not qualitative testing is desired
- QMP needs better tools and protocols for performance testing of the future.
  - Some are: currently under development
    not currently being addressed
- Pediatric imaging requires the QMP to be more involved operationally to properly manage both image quality and radiation dose with less down time of the fluoroscope.

"Our PACS is broken, but if you'll describe your pain in detail, our staff sketch artist will give us a fairly accurate drawing of the problem."