MANAGING PATIENT DOSE IN FLUOROSCOPIC PROCEDURES

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DILEMAS

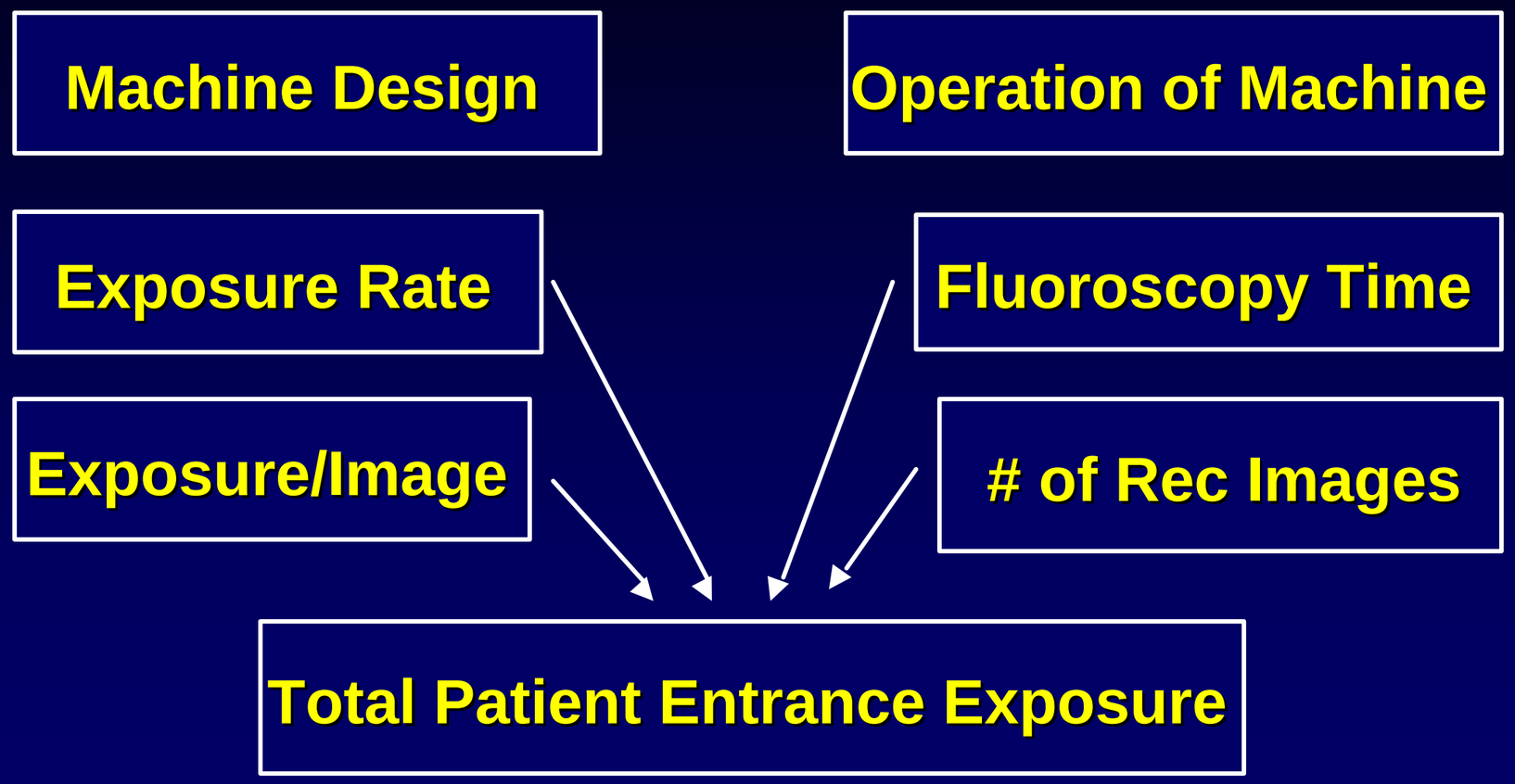
A. Fluoroscopically Guided Interventions
   1. Minor
   2. Life Saving
B. Deterministic Injuries
   1. None
   2. Severe
C. Responsible Physician Must Choose to Continue or Stop Complex Interventions

DILEMAS

D. Real-Time Data Needed to Balance
   1. Radiation Risk
   2. Clinical Benefit

E. Physician Hand Cuffed by:
   1. Regulatory Total Dose Limits
   2. Inappropriately Applied Reference Levels

MANAGING PATIENT DOSE



DILEMAS

F. Is Real-Time Data Over Kill?

1. Adults
   a. Complex Interventions
   b. Routine Interventions may not Require
2. All Pediatric Cases
   a. Elevated Radiosensitivity
   b. Multiple Follow Up Procedures

INTRODUCTION

A. Requirements of Patient Exam

B. Imaging Equipment Design Must be Exploited to Minimize Patient Dose

C. Acceptance Testing

D. Training of Staff

E. Real-Time Dose Monitoring Techniques

REQUIREMENTS OF PATIENT EXAM

A. Organ System(s) Studied
   1. Vascular
      a. Heart
      b. Arterial
      c. Venous
   2. Nonvascular
      A. Digestive Tract
      B. Drainages/Punctures

REQUIREMENTS OF PATIENT EXAM

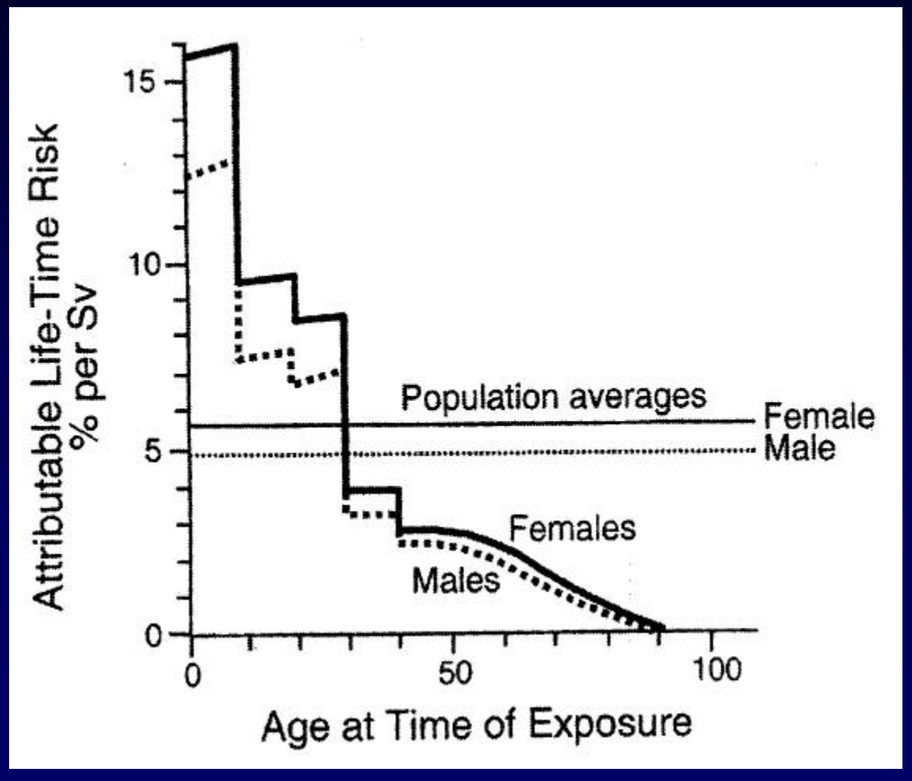
B. Patient Size Affects:

1. Image Quality Requirements
2. Patient Sensitivity to Radiation
3. Patient Dose
4. Required Ancillary Support
   a. Equipment
   b. Additional Staff

PATIENT STOCHASTIC RADIOSENSITIVITY

C. Radiation Induced Cancer Lifetime Risk From 1 Sv Whole Body Dose

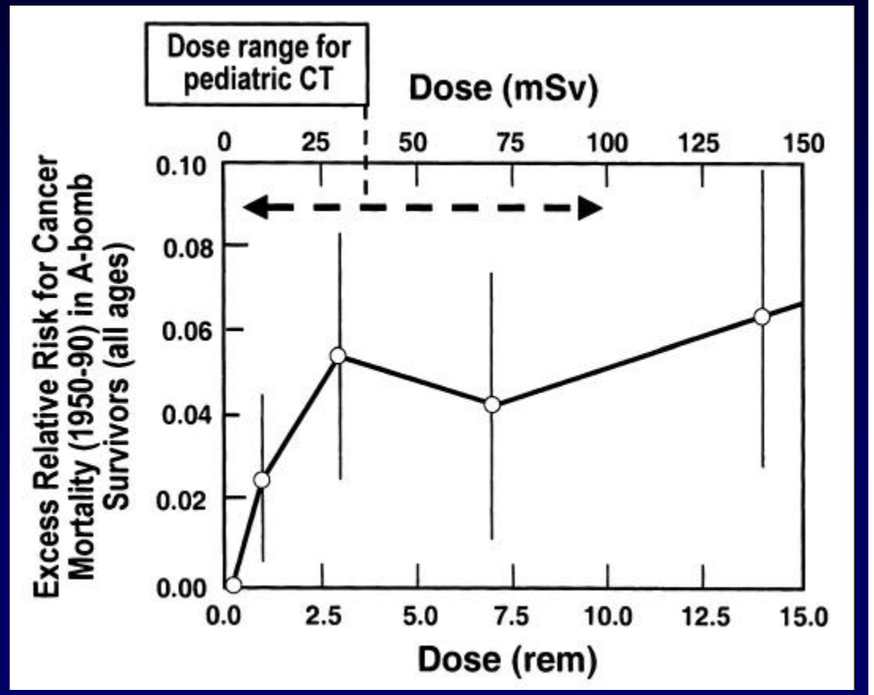
1. All Ages: 5%
2. 1st Decade: 15%
3. 2nd Decade: 8%
4. Middle Age 1 - 2 %
5. Child 10 times More Sensitive



PATIENT STOCHASTIC RADIOSENSITIVITY

D. Recent A-Bomb Survivor Data

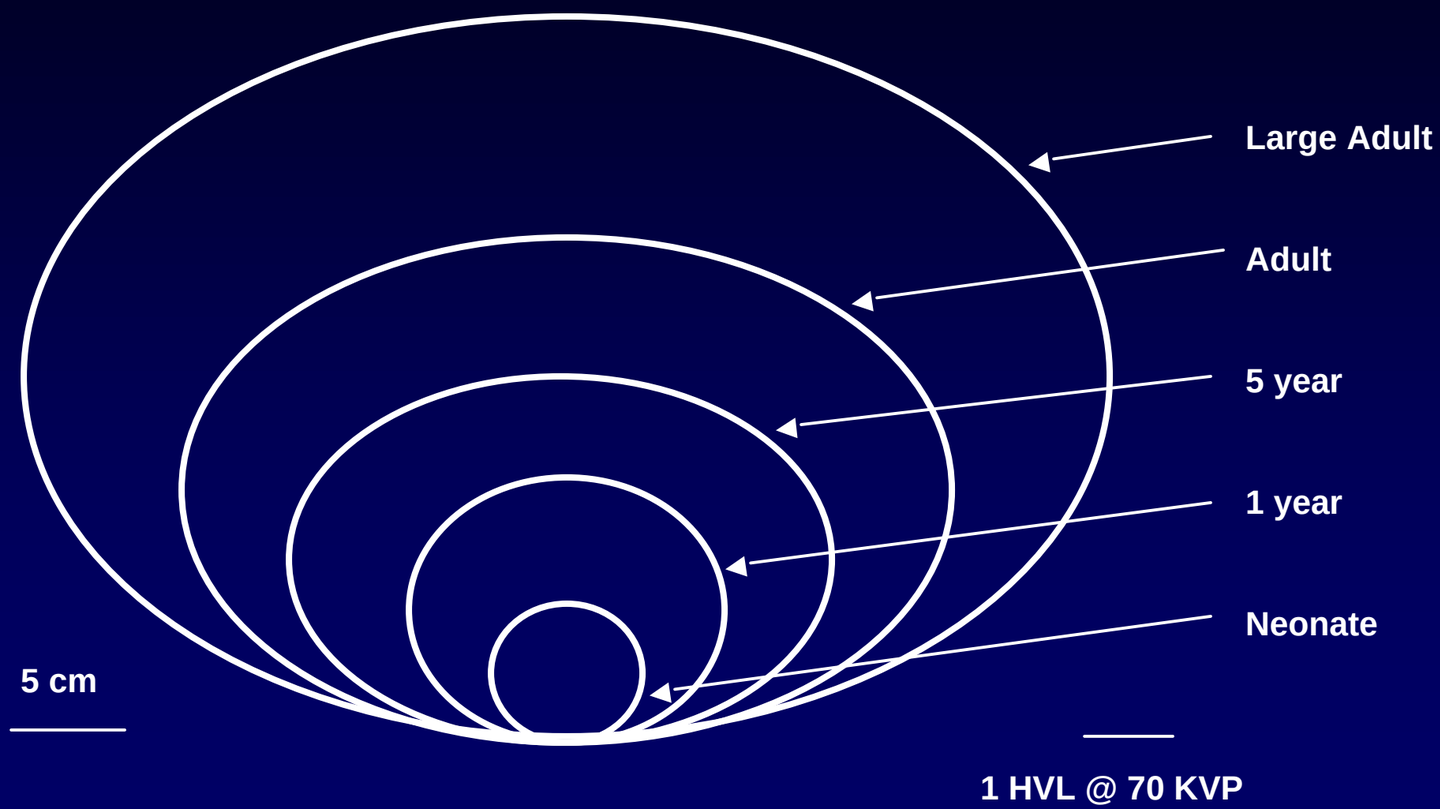
1. 35,000 Survivors
   Doses > 5 rad
2. Received Doses
   Over 50 Years Ago
3. Statistically Sig-
   nificant Excess
   Incidence of Cancer
   at Nonextrapolated
   Doses > 3 rads



PATIENTS COME IN ALL SIZES

	(kg)	Abdominal Girth Centimeters			
Age	Mass	PA	# HVL	LAT	# HVL
Neonate	2	6	2	6	2
Newborn	3	9	3	10	3.1
1 yr	10	12	4	14	4.6
5 yr	19	16	5.3	22	7.3
12 yr	31	18	6	27	9
Adult	68	22	7.3	33	11
Lrg Adult	130	32	10.6	48	16

PATIENTS COME IN ALL SIZES



PATIENTS COME IN ALL SIZES

E. Patient Doses Below 70 kVp Are Excessive

1. Newborn Fluoro Frame
   - a. 70 kVp & 0.01 mAs: 0.046 mR
   - b. 45 kVp & 0.08 mAs: 0.20 mR
2. Newborn Cath Frame
   - a. 70 kVp & 0.1 mAs: 0.46 mR
   - b. 45 kVp & 0.8 mAs: 1.98 mR
3. Newborn DSA Recorded Image
   - a. 70 kVp & 3 mAs: 14 mR
   - b. 45 kVp & 24 mAs: 110 mR

REQUIREMENTS OF PATIENT EXAM

F. Clinical Dynamic Range of mAs per Frame to Maintain Fixed kVp

1. PA Projection
   a. 9 Half Value Layers
   b. Range of 512!
2. LAT Projection
   a. 14 Half Value Layers
   b. Range of 16,000!

REQUIREMENTS OF PATIENT EXAM

G. Complexity
   1. Diagnostic Only
   2. Diagnostic & Interventional
      a. Deterministic Injuries

REQUIREMENTS OF PATIENT EXAM

G. Complexity Increases Deterministic Injury Risk

3. Clinical Problems of Children are Complex
   - a. Congenital Heart Defects and/or Diseases
     - i. “Black Box”
     - ii. 4 - 8 hr Exam Times
   - b. 100 - 200 minutes of Fluoro Can Occur
   - c. Malformations in Anatomy Corrected in Stages
     - i. Up to 10 catheterizations by 21st birthday
     - ii. Multiple interventions over weeks
     - iii. Radiation Damage to Skin is Cumulative

IMAGING EQUIPMENT DESIGN

VARIABLE RATE PULSED FLUOROSCOPY

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

1. Alternating if Biplane Configuration
   a. Scatter from Orthogonal Plane Eliminated
   b. Limited Subject Contrast Maintained
2. Variable Rate
   a. 30, 15, & 7.5 pulses/sec: Cath Lab
   b. 30, 15, 7.5, 4, & 3 pulses/sec: DSA Lab
   C. 7.5, 3.75, 1.88, 1 pulses/sec: GI/GU Lab

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

3. Image Quality vs Radiation Dose

a. Proper Pulse Width Minimizes Temporal Information Loss

b. Pulse Width Ranges

i. Pediatrics: 1 - 5 msec

ii. Adults: 3 - 10 msec

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

3. Image Quality vs Radiation Dose

c. Increased Perceived Noise Unacceptable if:

i. Exposure per pulse unchanged with reduced pulse rate

ii. Loss of Temporal Resolution is not the Cause of Rejection of Variable Rate Pulsed Fluoroscopy

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

3. Image Quality vs Radiation Dose

c. Perceived Noise Compensation

ii. EERIR/Frame $\propto$ 1/(Pulse Frequency)$^{1/2}$

- Less frame integration by eye
- EERIR/Frame Increased as Pulse Rate Decreases
- Relationship holds above 5 pulses/sec

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

4. Tube Current

a. Minimum: 10 mA

b. Maximum: 100 mA

5. Desired Fixed High Voltage ~ 70 kV

a. Requires mAs Range of 500!

i. Too many vendors do not vary tube current and pulse width!

ii. At best have a mAs range of 50

6. 70 kVp may Occur for Only One Size Patient!

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

7. Traditional Modulation of Technical Factors

a. Pulse Width at Maximum

b. Tube Current

i. Fluoro: 50 mA

ii. Acquistion: Maximum Tube Loading

c. kVp Modulated

i. Minimized for Large Patients

ii. Excessive Dose for Small Patients

IMAGING EQUIPMENT DESIGN

A. Variable Rate Pulsed Fluoroscopy

8. Preferred Modulation of Technique Factors

a. Starting Values

i. 70 kVp

ii. 3 msec

b. Modulation Hierarchy

i. Tube Current

ii. Pulse Width

iii. High Voltage

IMAGING EQUIPMENT DESIGN

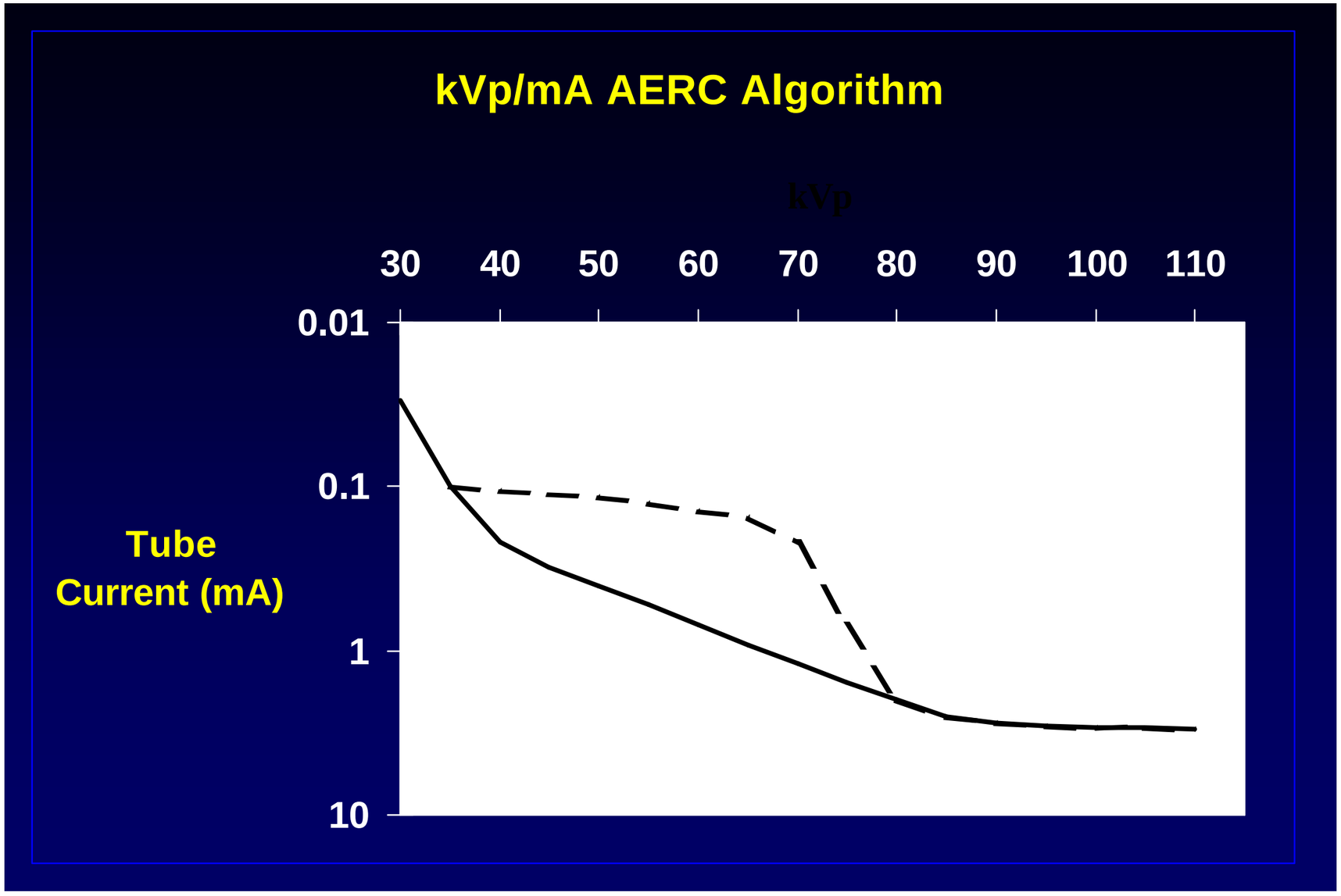
B. Continuous Fluoroscopy

1. Preferred Technique Modulation

a. Starting kVp: 70

b. Tube Current Modulated: 0.1 - 4 mA

c. kVp Modulated Last


kVp/mA AERC Algorithm
kVp
30
40
50
60
70
80
90
100
110
0.01
0.1
1
10
Tube
Current (mA)

IMAGING EQUIPMENT DESIGN

C. Variable Rate Radiographic Acquisitions

1. Cath Lab
   a. Same Specifications as Pulsed Fluoro Except:
      i. Variable Rate: 60, 30, & 15 pulses/sec
      ii. Tube Current:
         - Neonate to 2 Yr: 100 mA
         - 2 - 12 Yr: 300 - 400 mA
         - 12 Yr - Adult: Maximum Tube Loading
      iii. High Voltage ~ 70 kV for Patients < 12 Yr

IMAGING EQUIPMENT DESIGN

C. Variable Rate Radiographic Acquisitions

2. Vascular Lab

a. Variable Rate: 7.5 - 0.5 pulses/sec

b. Tube Current

i. Neonate to 2 yr: 200 mA

ii. 2 - 6 Yr: 400 - 600 mA

iii. 6 Yr - Adult: Maximum Tube Loading

c. High Voltage ~ 70 kV for Patients < 12 Yr

IMAGING EQUIPMENT DESIGN

C. Variable Rate Radiographic Acquisitions

3. Preferred Technique Modulation :

a. Starting Values

i. 70 kVp

ii. 3 msec

b. Modulation Hierarchy

i. Tube Current

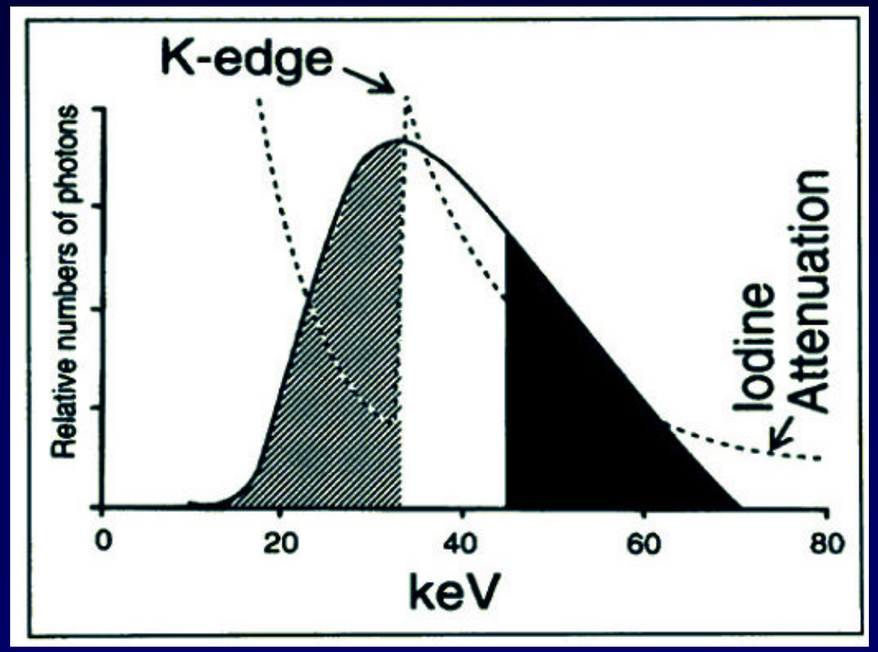
ii. Pulse Width

iii. High Voltage

IMAGING EQUIPMENT DESIGN

D. Spectral Beam Filtration: Change in Quality of X-ray Spectrum: **Match Energy of X-rays to Absorption of Contrast Media**

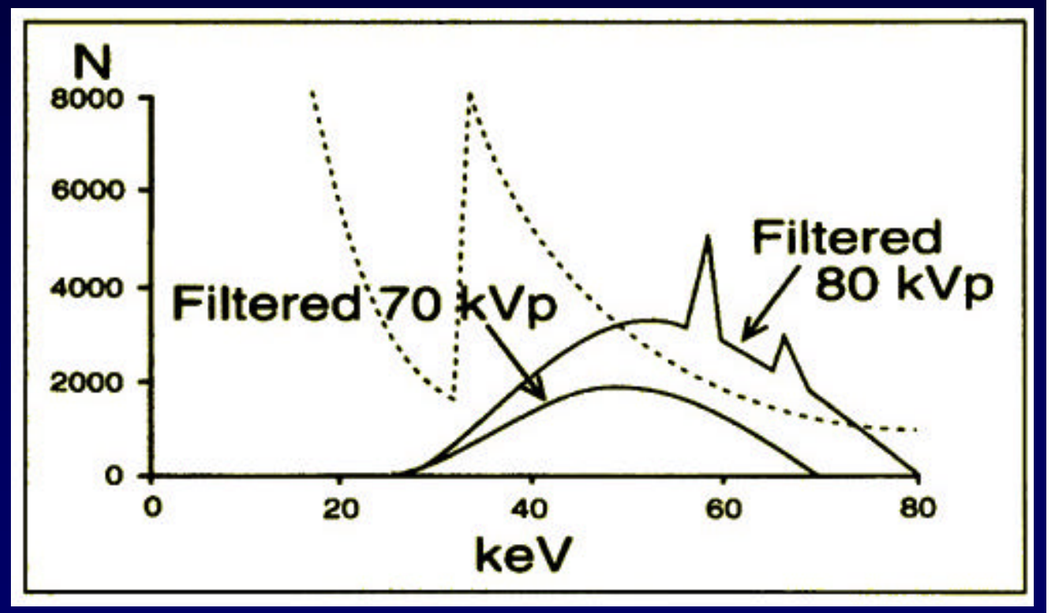
1. **Pass** 33 - 40 keV X-rays
2. **Attenuate**
   a. <33 keV X-rays Affects Dose
   b. > 40 keV X-ray Affects Contrast



IMAGING EQUIPMENT DESIGN

D. Spectral Beam Filtration:

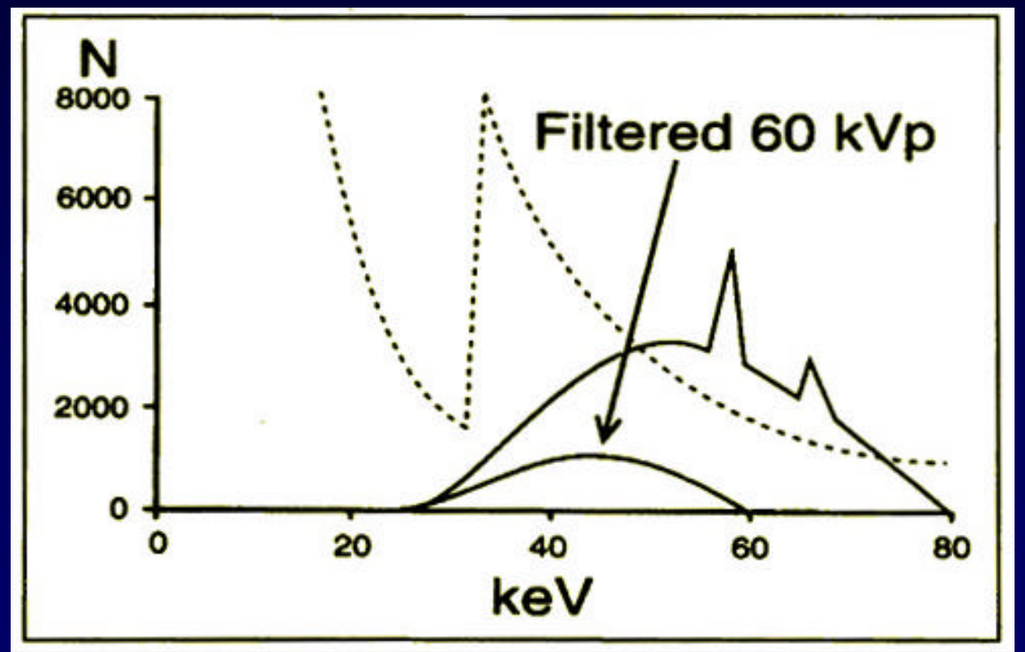
3. X-ray Tube Continuous Loading > 2 kW
4. 0.1 - 0.9 mm Cu Filtration
5. Low Energy Attenuated
6. kVp Increases
7. Excessive Effective keV



IMAGING EQUIPMENT DESIGN

D. Spectral Beam Filtration:

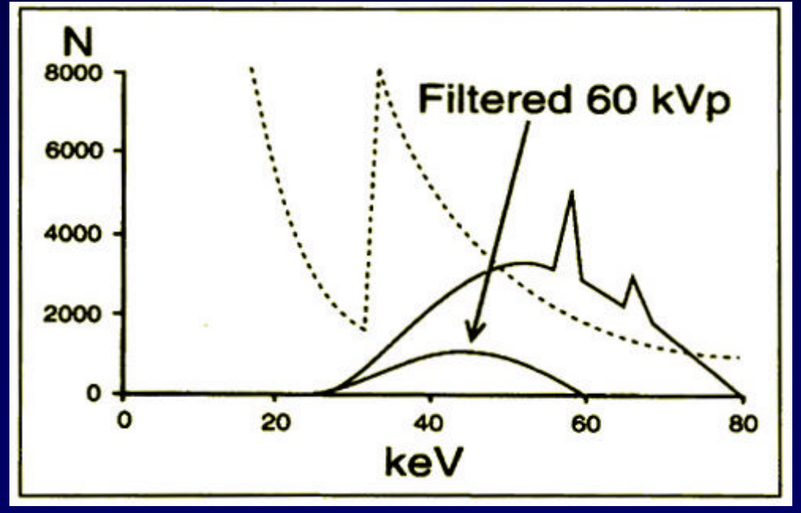
8. Modify Algorithm Controlling kVp & mA
9. kVp Reduced to 60 kVp
10. X-ray Intensity Too Small

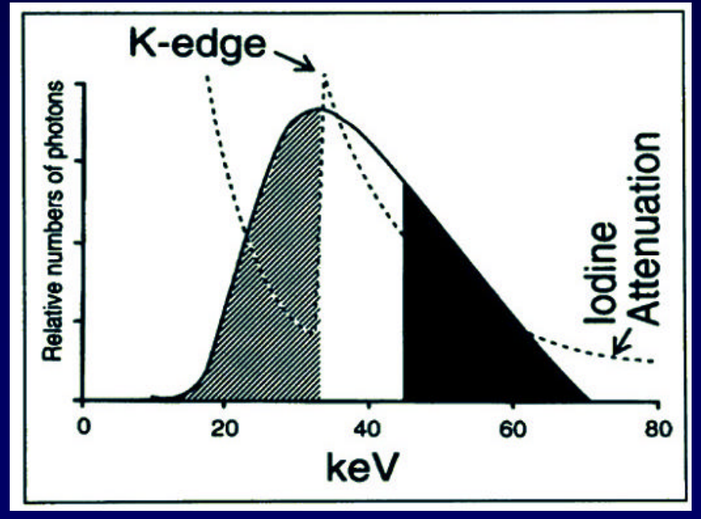


IMAGING EQUIPMENT DESIGN

D. Spectral Beam Filtration:

11. Increase mA to maximum kW
12. Adults: Fluoroscopy only ≤ 0.2 mm Cu
13. Pediatrics: Fluoroscopy & Radiographic





IMAGING EQUIPMENT DESIGN

D. Spectral Beam Filtration:

14. Summary

a. Added Filter

b. Reduced High Voltage

c. Increased Tube Current

d. Machine should automatically select:

i. Thickest filter

ii. Resulting in 60 - 70 kVp

iii. Based on current fluoro attenuation data

IMAGING EQUIPMENT DESIGN

E. Last Image Hold

1. Last Fluoroscopic Frame Stored and Continuously Displayed on TV Monitor
2. Poorer Quality due to Loss of Multiple Frame Integration by Eye
3. Allows Extended Viewing of Anatomy Without Further Radiation

IMAGING EQUIPMENT DESIGN

F. Fluoro Image Store

1. During Realtime Fluoroscopy
   a. Frame Selected by Operator and
   b. Electronically Stored
2. Poorer Quality due to:
   a. Loss of Multiple Frame Integration by Eye
   b. Lower Exposure at Plane of Image Receptor
3. Radiographic Acquisition Dose Avoided
4. Stored Fluoroscopic Frame Archived Electronically or on Film

IMAGING EQUIPMENT DESIGN

G. Spatial Beam Shaping

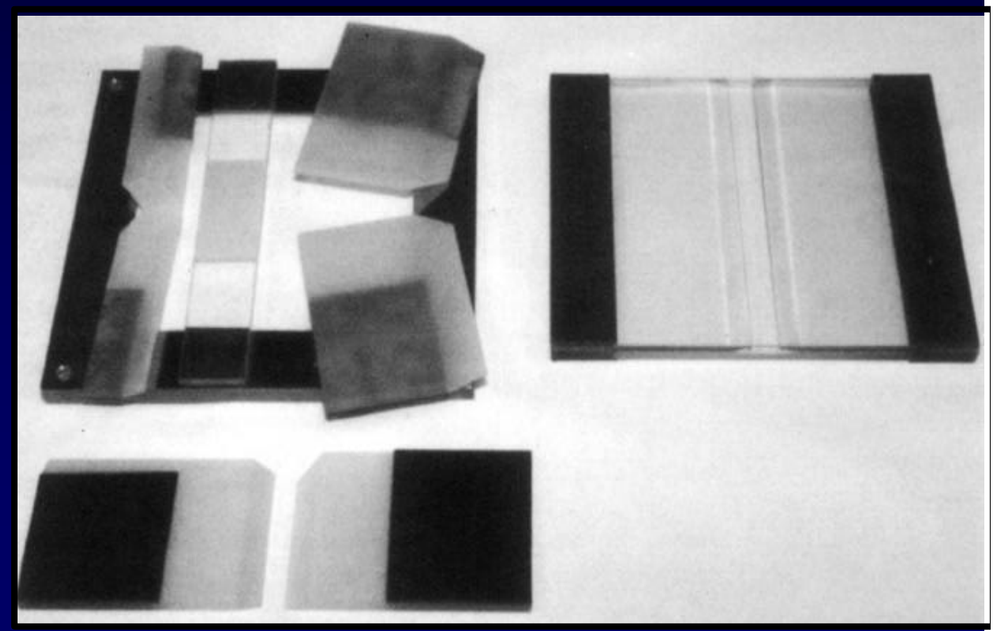
1. Equalization Filters: Attenuation Compensation

a. Linear & Rotational Movement

b. Tapered Lead - Acrylic Blades

c. Interchangeable

d. Integral Dose Reduction



IMAGING EQUIPMENT DESIGN

G. Spatial Beam Shaping

2. Collimator Adjustment without Fluoro Radiation

a. Collimator Blade Location Updated on Monitor as Blades are moved

b. Less Dose Due to Adjustment

c. Integral Dose Reduction

IMAGING EQUIPMENT DESIGN

H. Filtration Added to X-Ray Beam

"Spectral Beam" Filtering

1. Effective Energy of Beam Increases
2. Less X-rays @ same EERIR
3. Quantum Mottle Increases for same EERIR
4. Double EERIR wrt Standard Filtration
5. $EER_{filters} < EER_{std\ filters}$

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture in Front of TV Camera

1. Directly Controls EERIR

   Entrance Exposure Rate to Image Receptor

2. Indirectly Controls EER

   Entrance Exposure Rate to Patient

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

3. Pulse Fluoro Frequency Change

a. IIIER a 1/(Pulse Frequency)$^{1/2}$
for Pulse Frequencies > 5

b. Corrects Increased Perceived Noise
due to Less Integration of TV Frames
by Eye

c. EERIR/Frame a Constant
for Pulse Frequencies < 5

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

4. Function of FoV Change

a. Older Equipment With Fixed Aperture (II)

i. EERIR a $1/FoV^2$

ii. Corrects Loss of Minification Gain

iii. Maintained Brightness on Monitor

iv. Reduced Quantum Mottle

v. Significant Increase of EERIR in Mag modes

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

4. Function of FoV Change

b. Adjustable Aperture (II)

i. EERIR a 1/FoV

ii. Quantum Mottle (Absolute Noise) Independent of FoV

iii. Perceived Noise Increases with Sharper Image of Reduced FoV

iv. Correct with Increased EERIR

v. Less Increase of EERIR in Mag modes

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

4. Function of FoV Change

c. Adjustable Aperture Opened in Mag Modes

i. Conventional Image Intensifiers

ii. EERIR a Constant

iii. Increases in Perceived Noise Must be Tolerated by Operator

iii. Perceived Noise Increases with Sharper Image of Reduced FoV

iv. Patient Dose is Unchanged

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

4. Function of FoV Change

d. Flat Plate Image Receptors

i. EERIR a Constant

ii. Sharpness Minimally Affected by FoV

- Determined by Size of Plate's Pixels

iii. Perceived Noise is Constant

iv. Patient Dose Should be Unchanged

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

5. Operator Selectable EERIR:

Task Oriented

a. Low (Half of Medium)

b. Medium

c. High (Double Medium)

IMAGING EQUIPMENT DESIGN

I. Electronically Adjustable Aperture

5. Operator Selectable EERIR:

d. Manufacturer Dependent

e. Flat Plate Receptor Example (20 cm girth)

Parameter	Vendor A	Vendor B
Low EERIR (mR/m)	5.5	9.2
Low EER (R/m)	2.1	2.8
Nor EERIR (mR/m)	14	7.4
Nor EER (R/m)	5.8	4

ACCEPTANCE TESTING

A. Why Acceptance Testing?
   1. Identify & Eliminate Faulty Components
   2. Insure Proper Setup of Equipment
      a. Clinical Choices
         i. Clinical Requirements
         ii. Design Features of Equipment
      b. Measurement Techniques
         i. Test Equipment Available
         ii. Design Requirements of Clinical Unit

ACCEPTANCE TESTING

B. What Should be Measured?

1. Entrance Exposure Rate to Image Receptor
   a. All Fluoroscopic Modes
   b. All Recording Modes
2. Entrance Exposure Rate to Patient
   a. Maximum
   b. All Patient Sizes to be Imaged
3. Do Not Assume Installer has Addressed These Issues!!!!

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

1. $EERIR_{variable}$

a. $EERIR/Fr = (EERIR_{30}/Fr) / (\text{Pulse Frequency})^{1/2}$

b. $EERIR_{spectral\ filter} = 2 \times EERIR_{std\ filter}$

c. EERIR a $1/FoV^2$

d. EERIR a 1/FoV

e. EERIR a Constant (function of FoV Flat Plate)

f. $1/2 \times EERIR_{high} = EERIR_{normal}$

g. $EERIR_{normal} = EERIR_{low} \times 2$

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

2. EERIR?

a. Set EERIR to Provide Adequate Image Quality

b. Minimum EERIR

i. Equipment Design

ii. Image Quality Requirements

- Diameter of Vessel
- Concentration of Contrast Material

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

2. EERIR?

b. Minimum EERIR

i. Exposure a $1 / p^2c^2D^2$

p = precision

c = concentration of contrast

D = diameter of vessel

ii. Predicts Minimum Exposure to Detect Contrast Filled Vessels

iii. Predicts Improved Image Quality with any Reduced Perceived Noise (p^2)

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

2. EERIR?

c. Maximum EERIR

i. Perceived Noise a Function of System Noise

ii. System Noise = $[QM^2 + EN^2]^{0.5}$

QM = Quantum Mottle

EN = Electronic Noise

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

2. EERIR?

c. Maximum EERIR

iii. Want QM < EN

iv. When QM = EN Further Increases in EERIR are Wasted

v. Excessive EERIR Degrades Image Quality

- 10 R/min Limit
- Loss of Brightness on TV Monitor

ACCEPTANCE TESTING

Entrance Exposure Rate to Image Intensifier

22 cm FOV @ 80 kVp

Standard Filtration & kVp/mA Power Curves

30 Pulses per Second

Operational Mode	EERII Range (µR/frame)
Standard Fluoroscopy	1.5 - 2.5
High Dose Fluoroscopy	3 - 6
Digital Angiography	50 - 100
Digital Subtraction Angio	500 - 1000
Cardiac Digital	8 - 10
Cine Film	10 - 15

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

2. EERIR?

d. FPDER: Flat Plate Detector Exposure Rate

i. Standard Filtration & kVp/mA Power Curves

ii. 20 cm FOV @ 80 kVp

iii. 30 Pulses per Second

Operational Mode	EERIR Range (µR/frame)
Standard Fluoroscopy	2.5
Digital Angiography	50 - 100
Cardiac Digital	10 - 15

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

2. EERIR?

d. FPDER: Flat Plate Detector Exposure Rate

iv. Unchanged as FoV changes

v. Justification

- Measured Sharpness of image basically independent of FoV
- Sharpness of image similar to 5” FoV II

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

3. EER?

a. Entrance Exposure Rate

b. Where?

i. Patient’s Skin?

ii. Reference Point?

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

3. EER

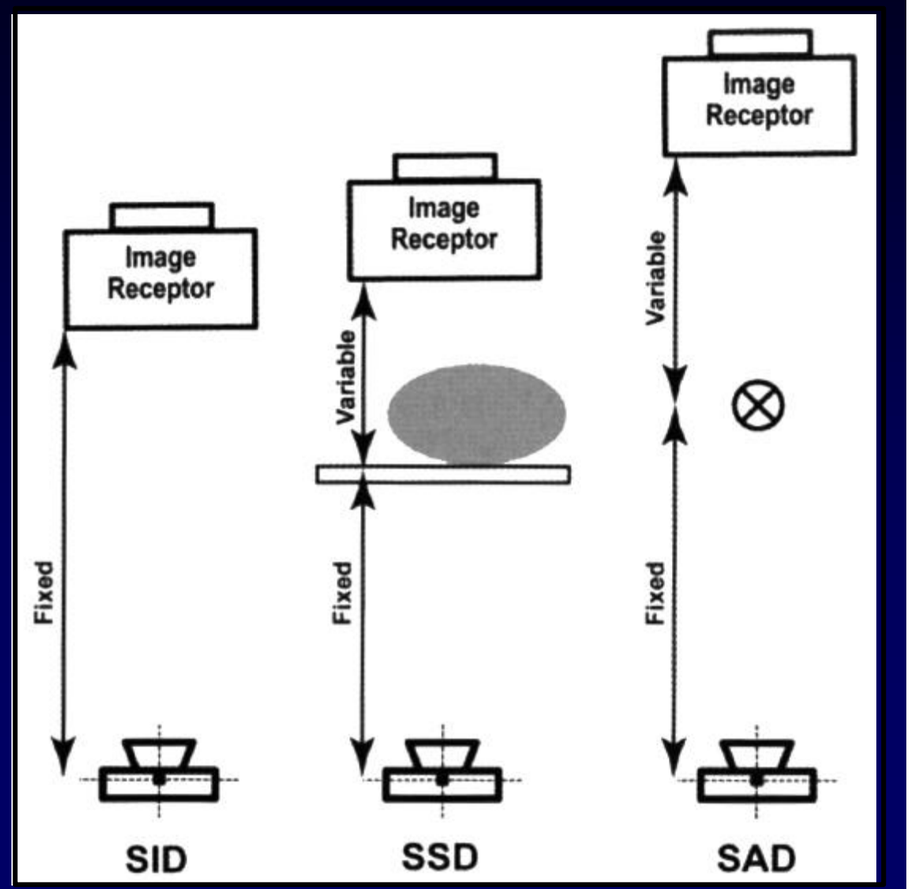
c. Three Fluoroscopic Geomentries:

<u>FIXED</u>

i. SID

ii. SSD

iii. SAD



ACCEPTANCE TESTING

C. Appropriate Performance Levels?

3. EER

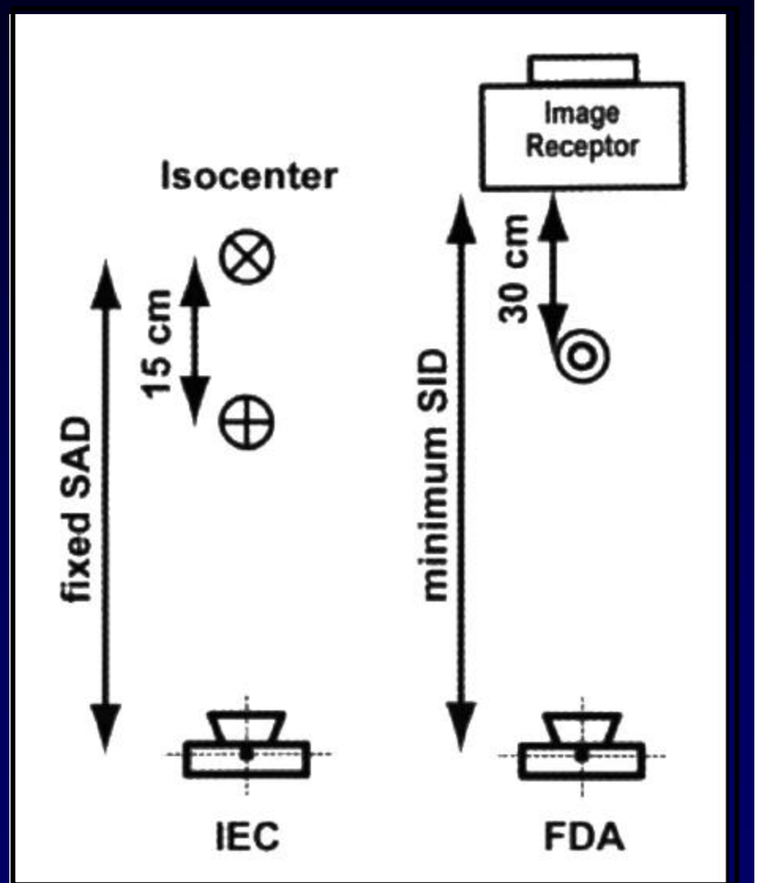
d. Common Dose Reference Points

i. IEC

15 cm

ii. FDA

30 cm



ACCEPTANCE TESTING

C. Appropriate Performance Levels?

3. EER

e. Other Important Parameters

i. a mA

ii. a kVp^2

iii. ~ a ~ EERIR

- Added Filtration
- Beam Shaping Filters
- Grid Factors

ACCEPTANCE TESTING

C. Appropriate Performance Levels?

3. EER

e. Other Important Parameters

iv. Function of Patient Size

v. a (1 / distance)^2

ACCEPTANCE TESTING

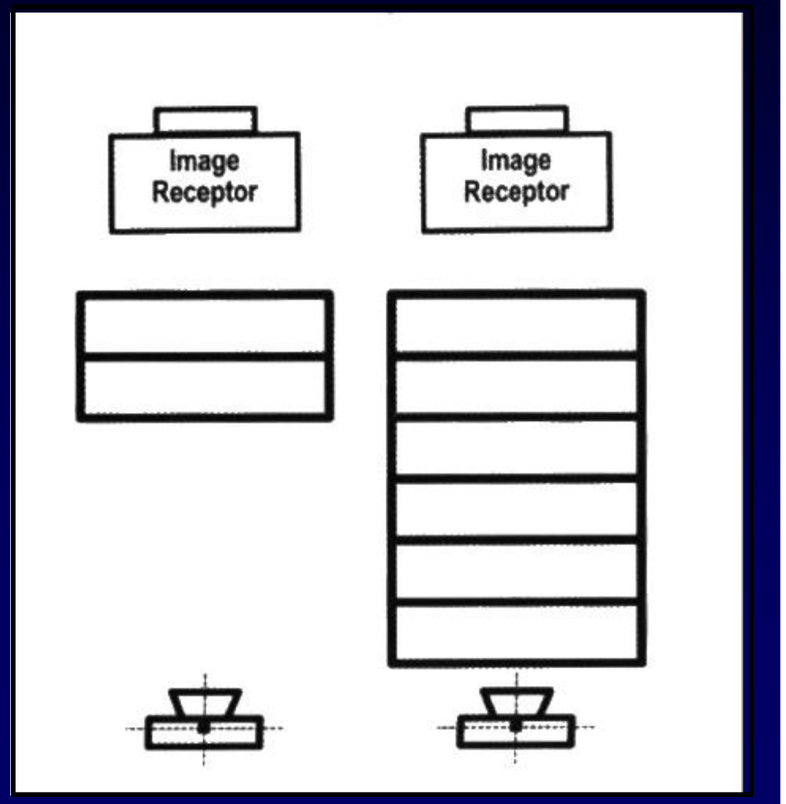
C. Appropriate Performance Levels?

4. Affect of Increasing Patient Size

a. Fixed SID

i. Attenuation?

ii. Shorter SSD?



ACCEPTANCE TESTING

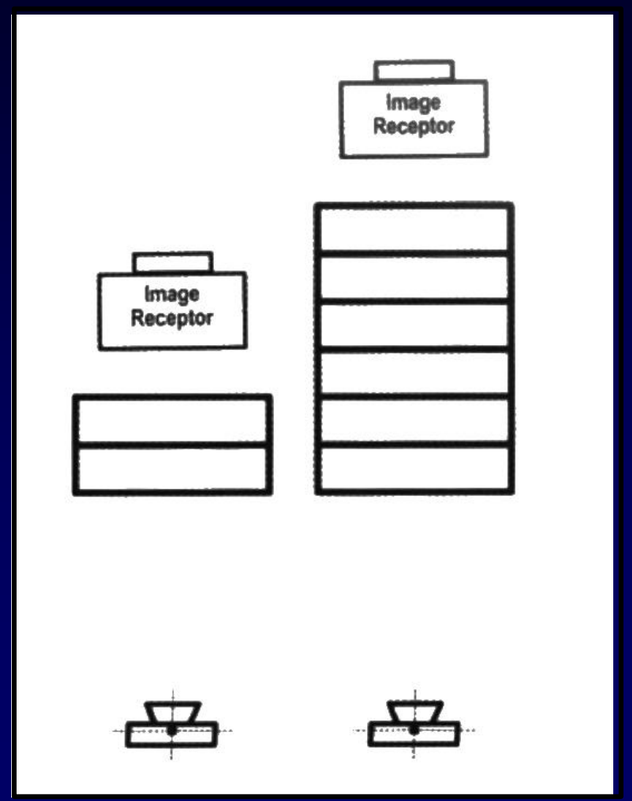
C. Appropriate Performance Levels?

4. Affect of Increasing Patient Size

b. Fixed SSD

i. Attenuation?

ii. Longer SID?



ACCEPTANCE TESTING

C. Appropriate Performance Levels?

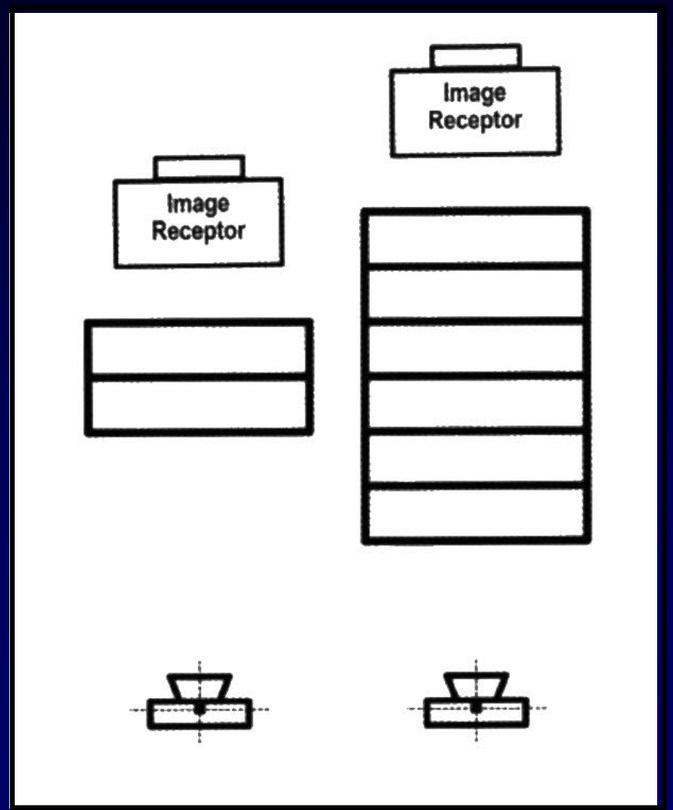
4. Affect of Increasing Patient Size

c. Fixed SAD

i. Attenuation?

ii. Longer SID?

iii. Shorter SSD?



ACCEPTANCE TESTING

D. Measurement Pitfalls

1. Dosimeter
   - a. Constant Energy Response
     - i. 50 - 120 kVp
     - ii. 2 - 14 mm Al HVL
   - b. Collection Efficiency

     95% @ 2,000 - 10,000 R/min
   - c. Leakage < 1 x 10^{-14} Amp

ACCEPTANCE TESTING

1. Dosimeter
   d. Shape of Ionization Chamber
      i. Parallel Plate
         - Fits behind Grids
         - High Collection Efficiency
         - X-ray “Transparency”
      ii. Cylindrical
         - No Directional Response

ACCEPTANCE TESTING

D. Measurement Pitfalls

2. Attenuation Phantom Materials

Material	Effective Z	Density	BE(keV)
Water	7.4	1.00	0.5
PMMA	6.6	1.19	0.5
Al (1100)	13	2.70	1.6
Copper	29	8.93	9.0

ACCEPTANCE TESTING

D. Measurement Pitfalls

2. Attenuation Phantom Materials

b. Required Phantom Material Thickness

i. Water: 25 cm

ii. PMMA: 25 cm

iii. Aluminum: 7.6 cm

iv. Copper: 0.8 cm

ACCEPTANCE TESTING

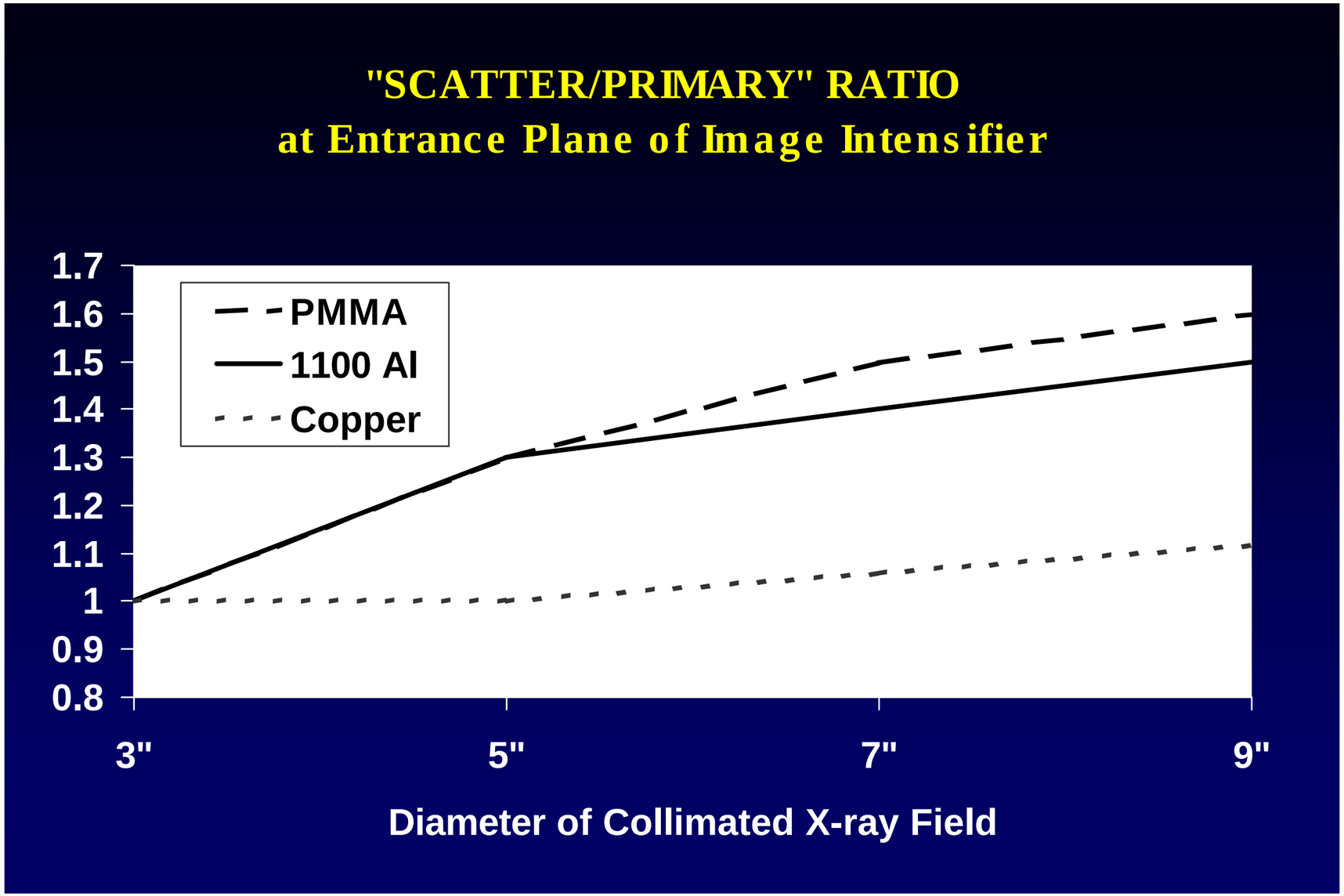
D. Measurement Pitfalls

3. Scatter/Primary Ratio

a. PMMA

b. 1100 Alloy Aluminum

c. Copper


"SCATTER/PRIMARY" RATIO
at Entrance Plane of Image Intensifier
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
PMMA
1100 Al
Copper
3"
5"
7"
9"
Diameter of Collimated X-ray Field

ACCEPTANCE TESTING

D. Measurement Pitfalls

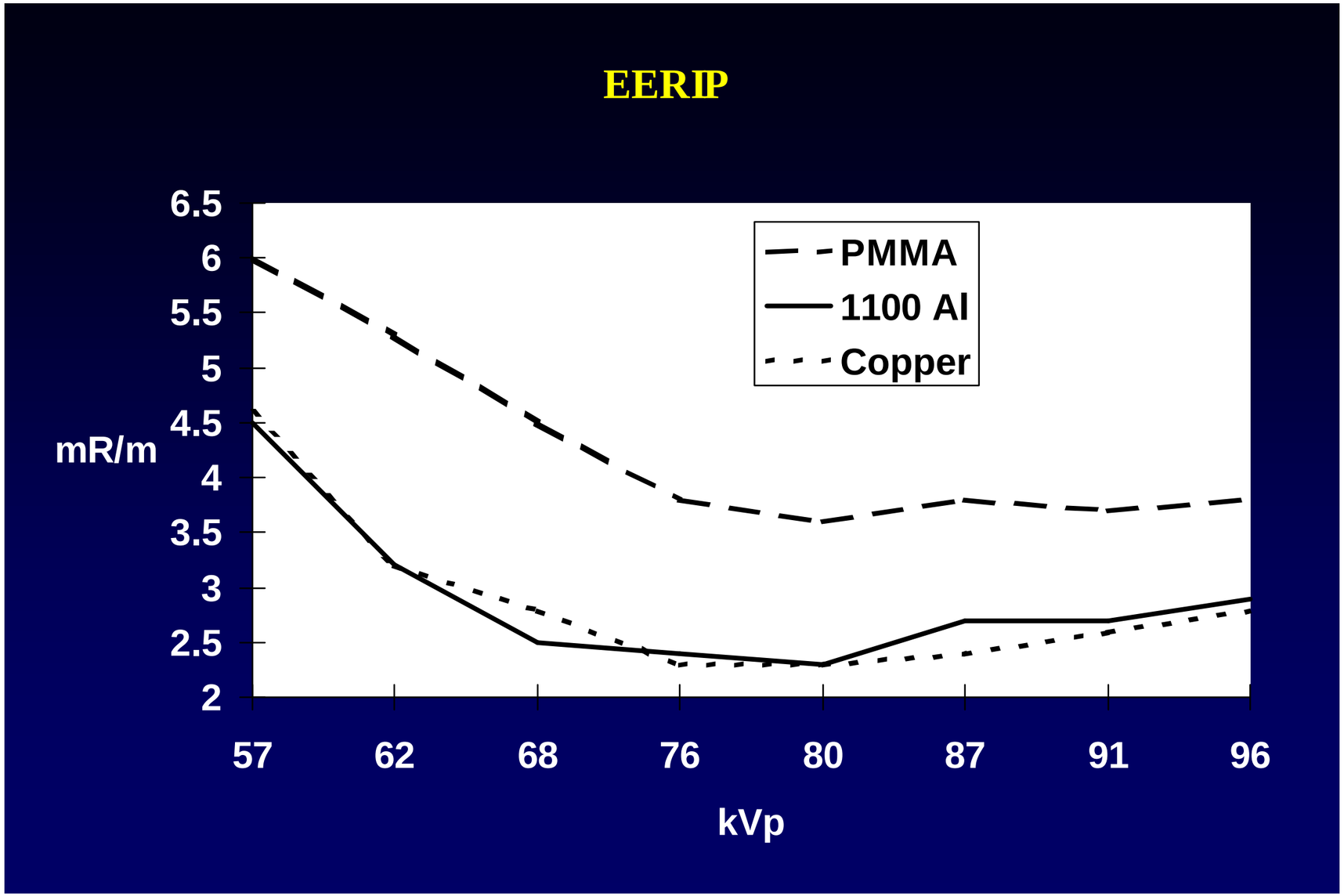
4. Affects of Effective Energy

a. $HVL_{23\ cm\ water}$ ~ $HVL_{0.5\ mm\ Cu}$

b. Measured EERIR Differences

i. $EERIR_{Al}$ ~ $EERIR_{Cu}$

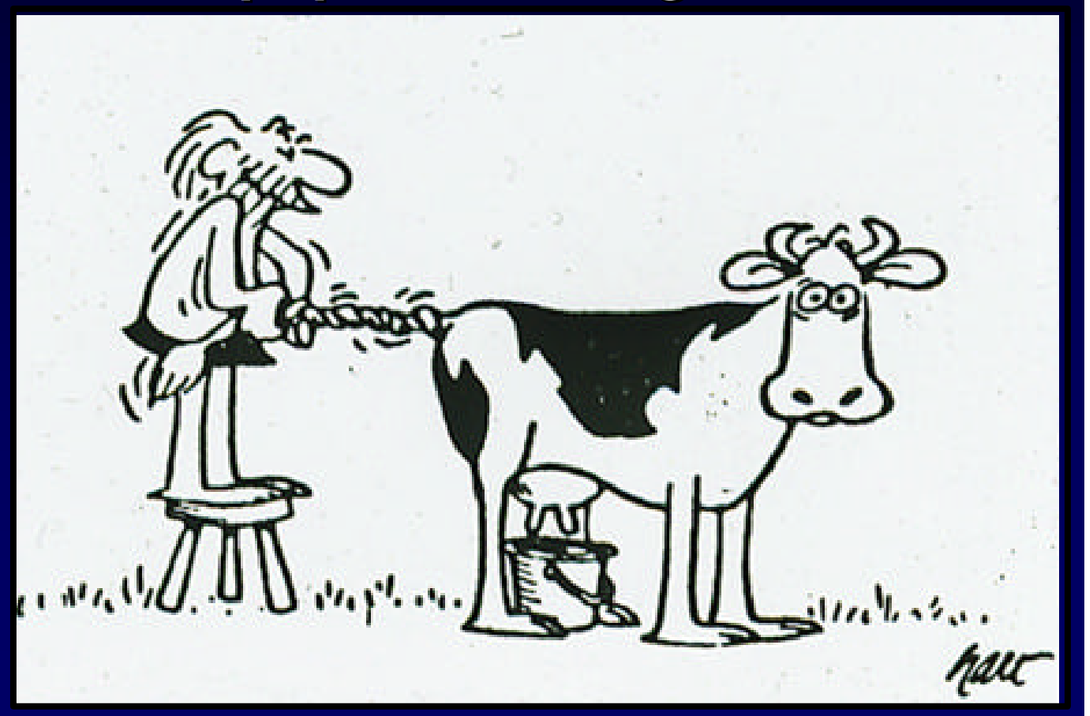
ii. $EERIR_{PMMA}$ ~ 1.5 x $EERIR_{Cu}$


EERIP
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
mR/m
PMMA
1100 Al
Copper
57
62
68
76
80
87
91
96
kVp

TRAINING OF STAFF

A. Comprehensive Training Fosters

1. Full Utilization of Equipment Design
2. Optimum Image Quality
3. Reduced Radiation Dose



TRAINING OF STAFF

B. Types of Training

1. Core Knowledge Provided at Regular In-Services
   a. Basic Imaging Principles
   b. Quality Control Responsibilities
   c. Equipment Care & Maintenance
   d. Radiation Protection Principles

TRAINING OF STAFF

B. Types of Training

1. Core Knowledge

d. Radiation Protection Principles

i. Principles of X-Ray Production

ii. Patient/Operator Geometries

iii. Appropriate Use of Shielding Devices

iv. Credentialling Program

TRAINING OF STAFF

B. Types of Training

2. "Buttonology": Unique Operational Features of Imaging Equipment

a. Establish Lead Operators

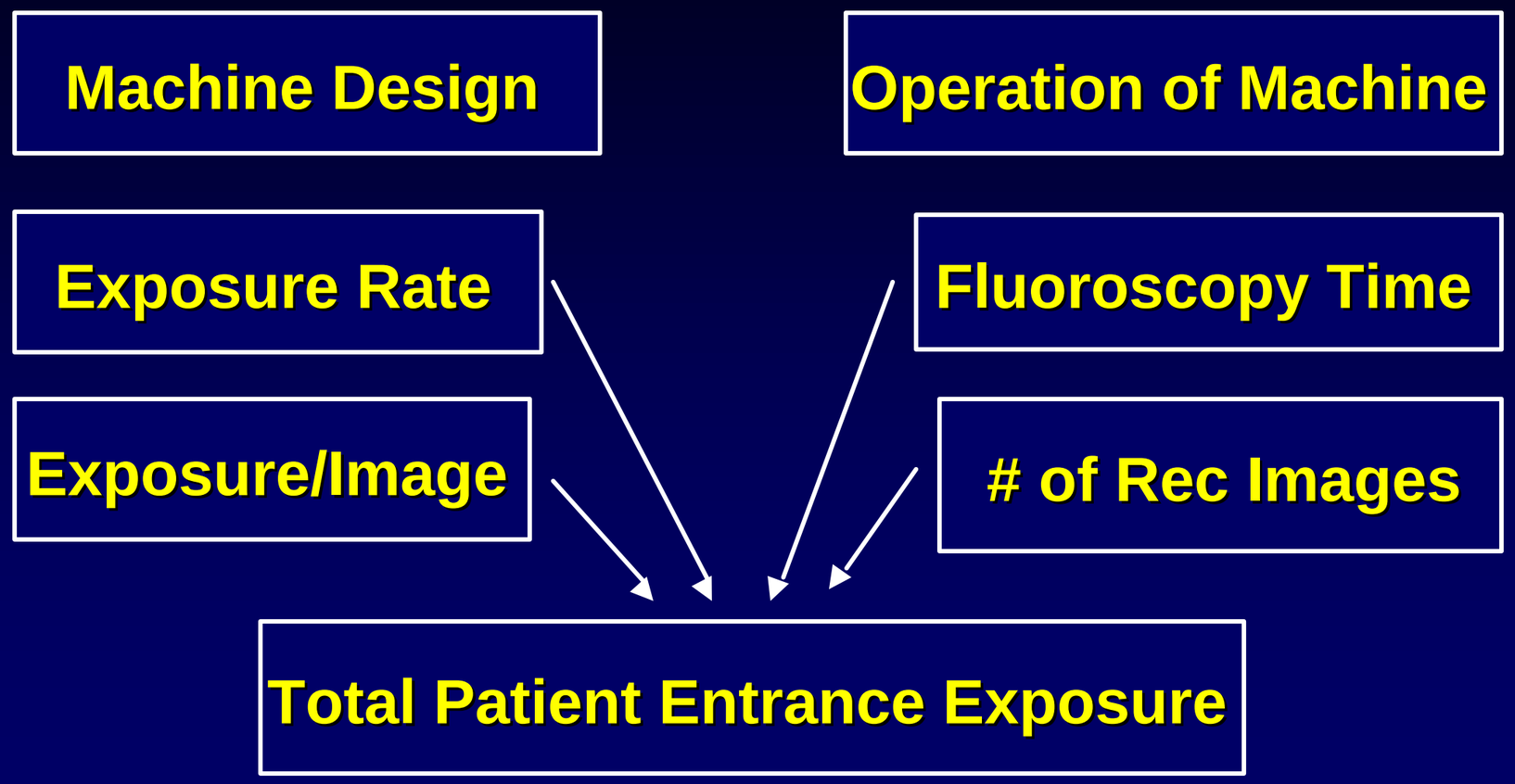
b. Other clinical sites

c. Vendor's headquarters

d. Phantom Imaging on Site

e. First patients

MANAGING PATIENT DOSE



CLINICAL MEASUREMENTS

A. GOALS

1. Allows **Informed Risk-Benefit Decisions** During Study
2. Document **Individual** Clinical Exposures
3. Allows **Management** of:
   a. Radiation Risks to Patients and Personnel
   b. Changes in Equipment Performance

CLINICAL MEASUREMENTS

B. Additional Reading

Balter S, Shope TB, Fletcher DW, Kuan HM, Seissl H. "Techniques to Estimate Radiation Dose to Skin During Fluorosopically Guided Procedures"

1992 AAPM Summer School Proceedings

CLINICAL MEASUREMENTS

B. What is the Best Indicator of Patient Risk?

1. Historical Measurements Limited by Available Instrumentation
   a. Fluoroscopy Time
   b. TLD Skin Dose Measurements
   c. Cumulative Skin Dose
   d. Peak Skin Dose

CLINICAL MEASUREMENTS

C. Fluoroscopy Time Limitations

1. Fluoro Dose Rates Vary Over Wide Range
   a. Patient Size
   b. kVp
   c. mA
   d. Beam Orientation
   e. FoV
   f. Source Skin Distance
   g. Spectral Beam Filtration
2. Dose from Recorded Images Ignored

CLINICAL MEASUREMENTS

D. Cumulative Dose
   1. Total Dose Delivered During Exam
   2. Can be Measured Real-Time
   3. Indirect Measurement
      a. Estimates Dose at Reference Point
      b. Based on Direct Measurements at Other Locations

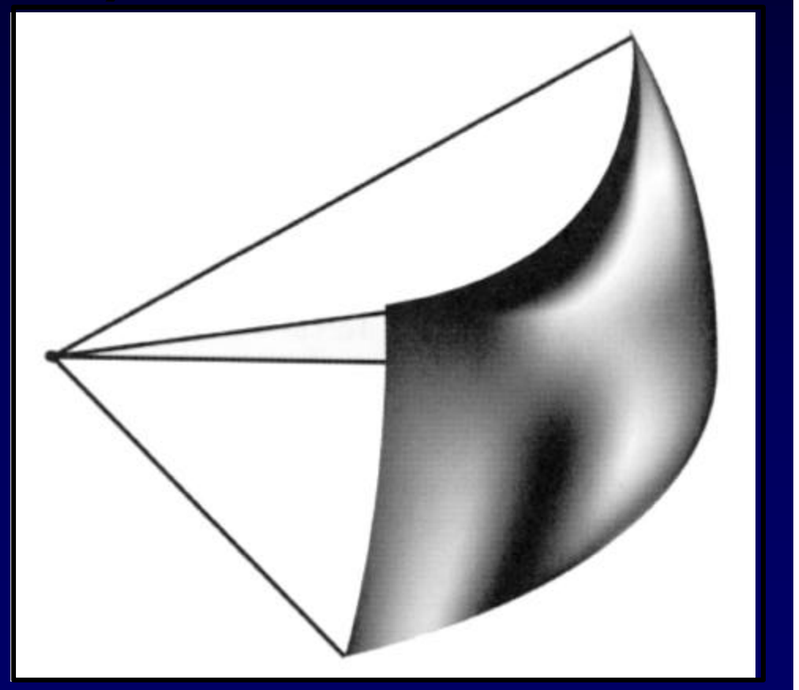
CLINICAL MEASUREMENTS

D. Cumulative Dose

4. Dose-Area-Product (DAP)

a. Integral of Dose Across Entire X-Ray Beam

b. Estimates Upper Limit of Total Energy Absorbed by Patient



CLINICAL MEASUREMENTS

D. Cumulative Dose

4. DAP

a. Isocenter

b. Dose Reference Point

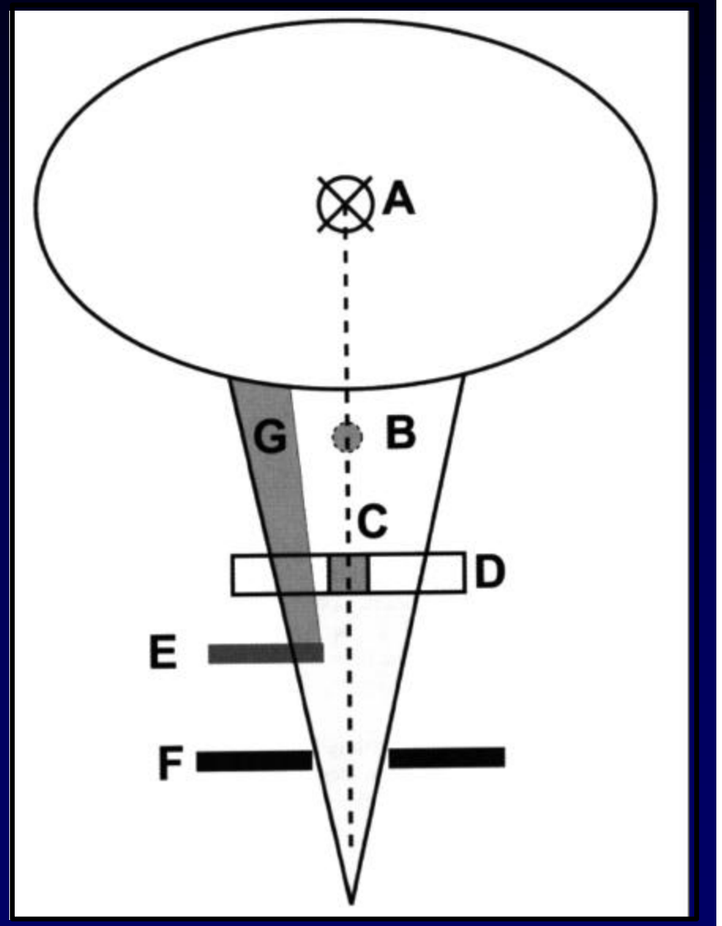
c. KERMA chamber

d. DAP chamber

e. “Wedge” Filter

f. Collimator Blade

g. Reduced Dose Area



CLINICAL MEASUREMENTS

D. Cumulative Dose

4. DAP

c. Advantages

i. Simple Installation & Calibration

ii. Independent of Distance From Focal Spot

iii. Teaching Tool of Scatter Production

iv. Indication of Integral Dose

CLINICAL MEASUREMENTS

D. Cumulative Dose

4. DAP

c. Disadvantages

i. No Correction for Table Top Attenuation

ii. Source to Skin Distance?

iii. Spatial Distribution of Entrance Beam?

iv. Overestimates Possibility of Exceeding Deterministic Threshold

v. Inaccurate Skin Dose Estimations

CLINICAL MEASUREMENTS

D. Cumulative Dose

5. Derived Patient Exposure

a. Exposure Rate and

b. Cumulative Exposure to Reference Point

From Real-Time Data Within X-ray System

CLINICAL MEASUREMENTS

D. Cumulative Dose

5. Derived Patient Exposure

c. Required Data

i. KiloVoltage

ii. Tube Current

iii. Time

iv. Source Skin Distance

v. Calibration Algorithms

vi. Patient Support Attenuation

CLINICAL MEASUREMENTS

D. Cumulative Dose

5. Derived Patient Exposure

d. PEMNET®

i. Advantages

- 5% Accuracy
- Database Provided
- Real-Time Displays

CLINICAL MEASUREMENTS

D. Cumulative Dose

5. Derived Patient Exposure

d. PEMNET®

i. Disadvantages

- Additional Cabling
- Noise Free Interfaces
- Involved Calibration
- Database Maintenance
- Spatial Distribution of Entrance Beam?

CLINICAL MEASUREMENTS

E. Peak Skin Dose (PSD)

1. Peak Skin Dose ? Cumulative Dose

a. Entrance Port Moves During Exam

i. Beam Orientation

ii. Field of View

b. Dose for Given Port

i. On-Time

ii. Intensity

- Patient Size
- Beam Orientation

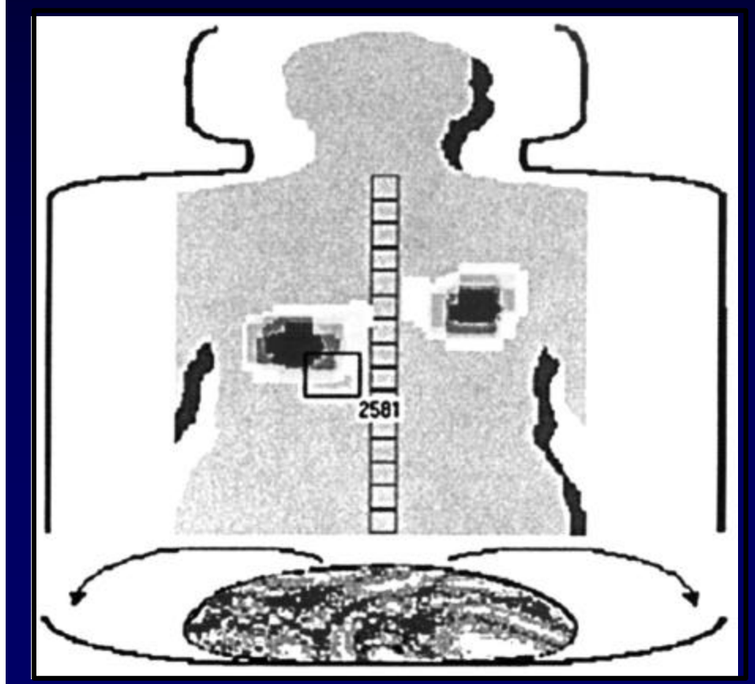
c. Overlap of Ports

CLINICAL MEASUREMENTS

E. PSD

2. Derived Patient Exposure

a. CareGraph®



i. Skin Flattened

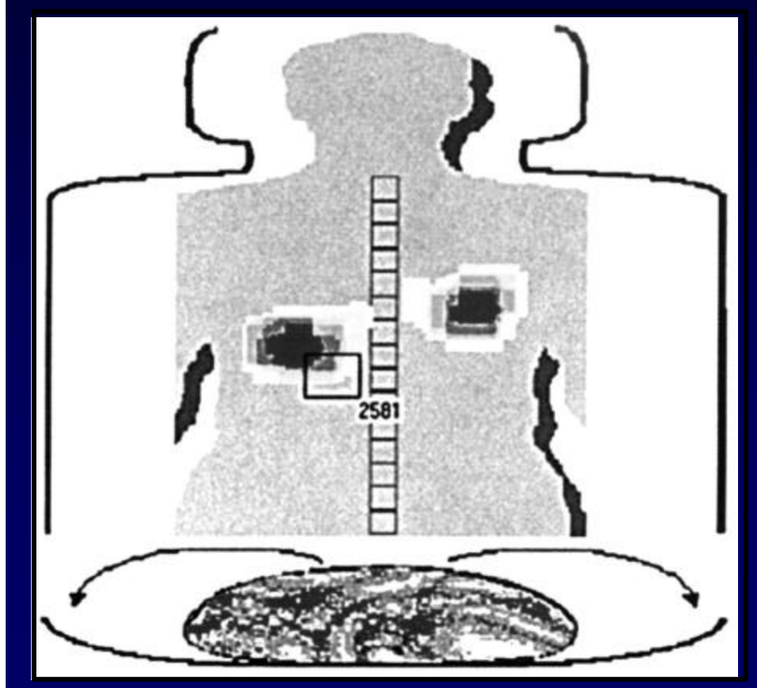
- Back Centered
- Anterior Midline at Right and Left Boarders
- PSD Listed in Black
- Colors Indicate Dose
- Black Rectange is Current Port

CLINICAL MEASUREMENTS

E. PSD

2. Derived Patient Exposure

a. CareGraph®

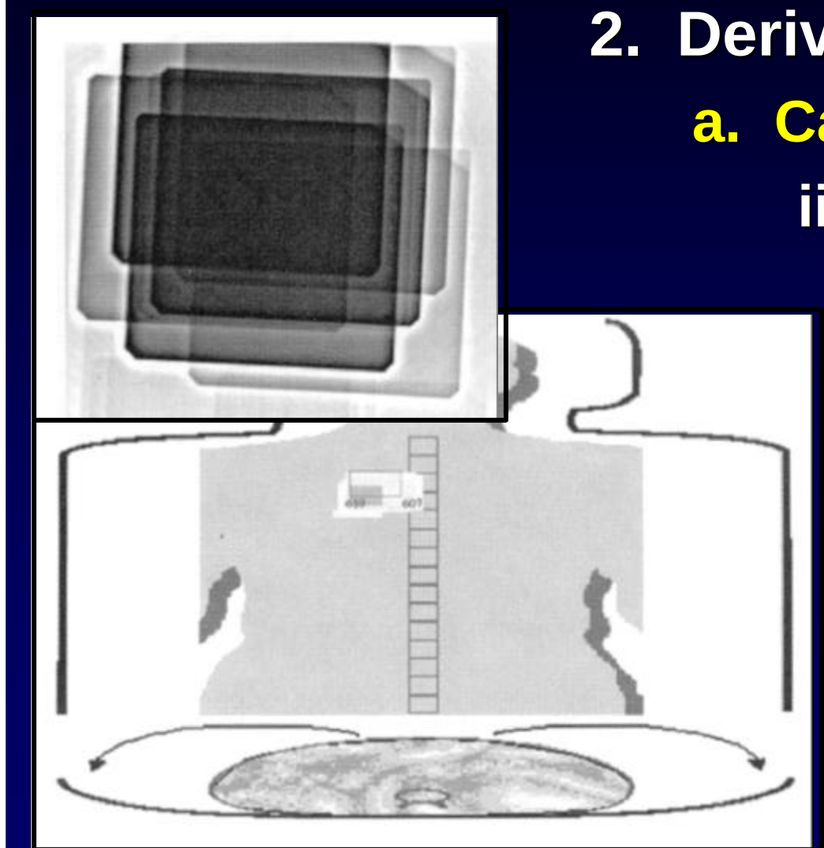


ii. Other Numeric Displays

- Fluoroscopy Time
- Cumulative Dose
- DAP
- Peak Skin Dose

CLINICAL MEASUREMENTS

E. PSD



2. Derived Patient Exposure

a. CareGraph®

iii. Disadvantages

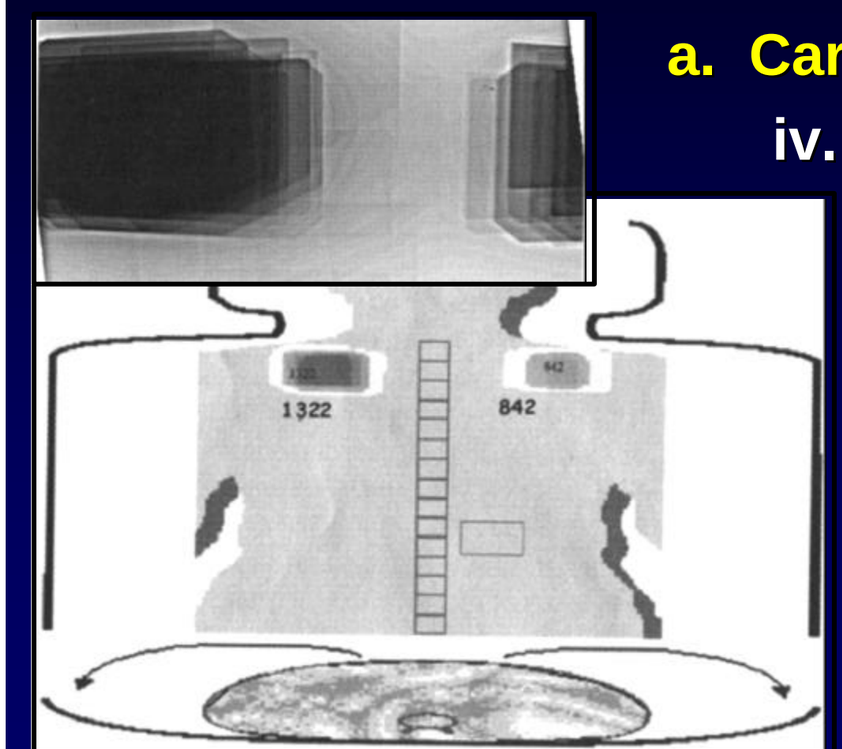
- No Longer Available
- Skin Modeled to One Standard Adult Body
- Information from Individual Ports is More Limited than Film

CLINICAL MEASUREMENTS

E. PSD

2. Derived Patient Exposure

a. CareGraph®



iv. Advantages

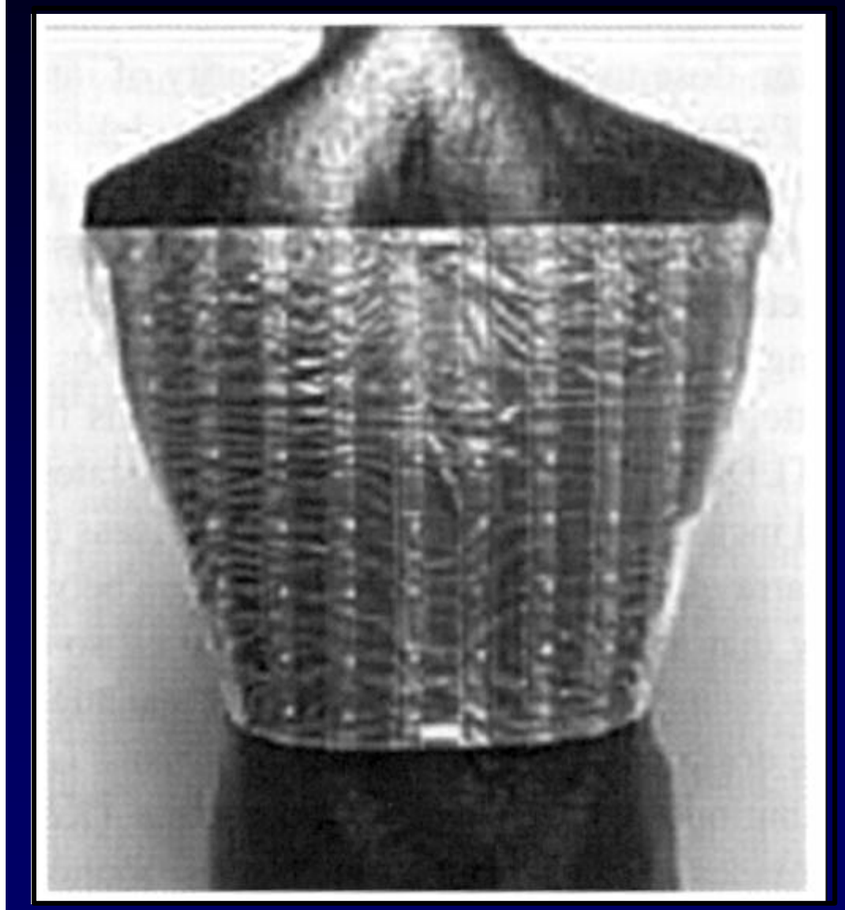
- More Flexible than Film
- Real-Time Reduction of PSD by Changing Angles Collimation, or Table Location

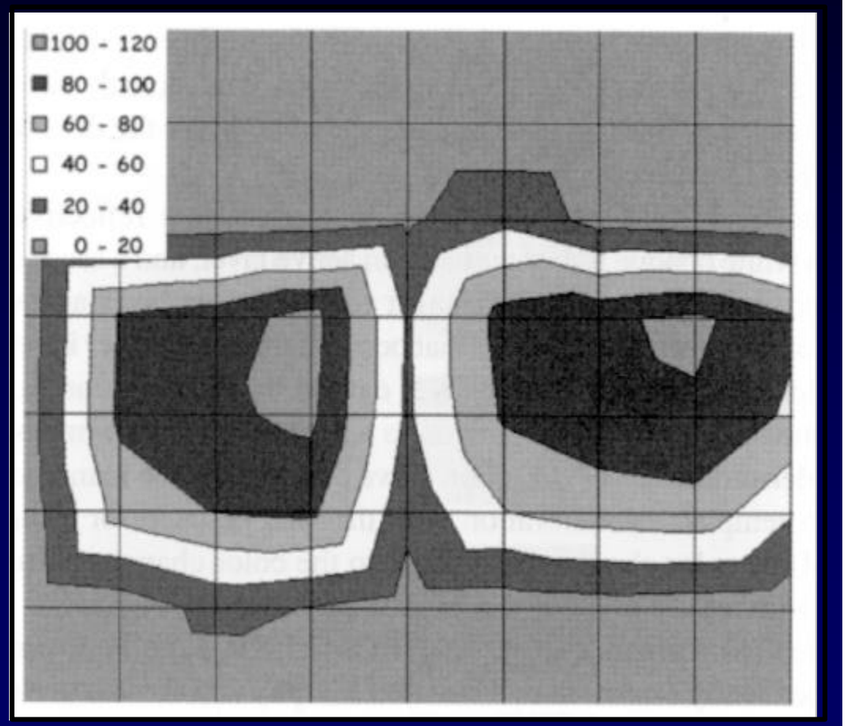
CLINICAL MEASUREMENTS

F. Other Direct Measures of Skin Dose

1. Thermoluminescent Dosimetry (TLD)
   a. Advantages
      i. Small Size
      ii. Are Not Imaged
   b. Disadvantages
      i. Post Exposure Processing Required
      ii. No Real-Time Feedback to Operator
      iii. Location of PSD Must be Known

CLINICAL MEASUREMENTS





CLINICAL MEASUREMENTS

F. Other Direct Measures of Skin Dose

2. X-Ray Film Dosimetry

a. Advantages

i. Dose Distribution Illustrated

ii. Can be Used with any X-ray Unit

iii. Can Provide Quantitative Dose Info

b. Disadvantages

i. Limited Range

ii. Factors Affecting Film Sensitivity

iii. Positioning wrt to the patient

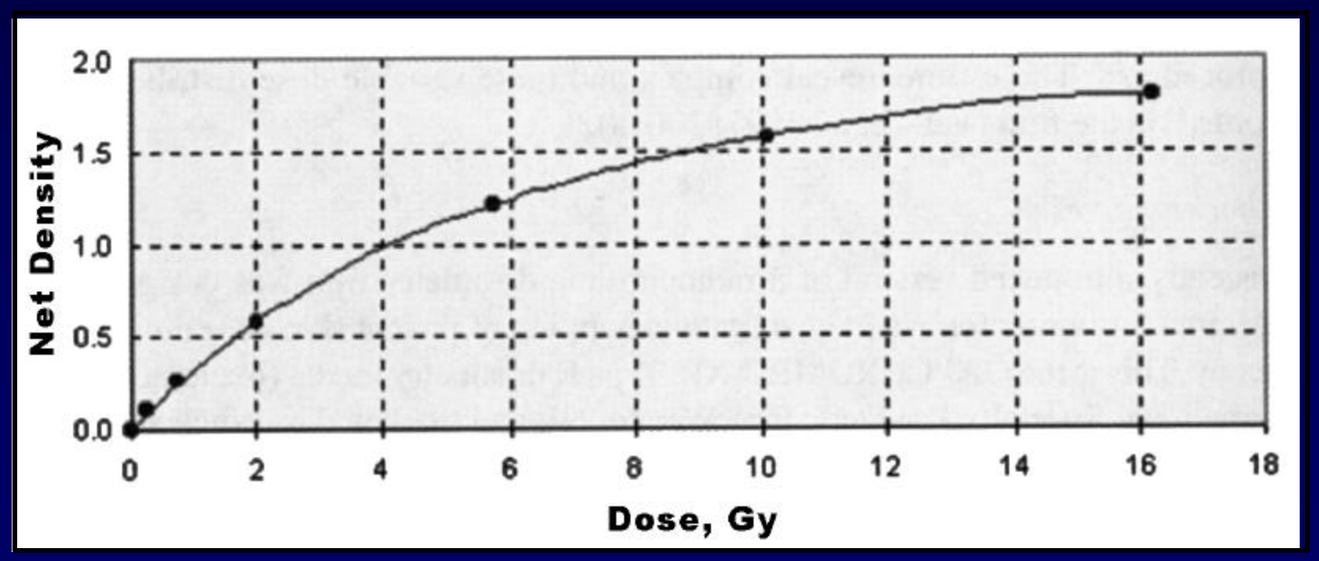
iv. No Real-Time Feedback

CLINICAL MEASUREMENTS

F. Other Direct Measures of Skin Dose

3. Radiochromatic Film (GAFCHROMIC XR-Type R)

a. Chemical Radiation Sensors that Change Color in Response to Exposure

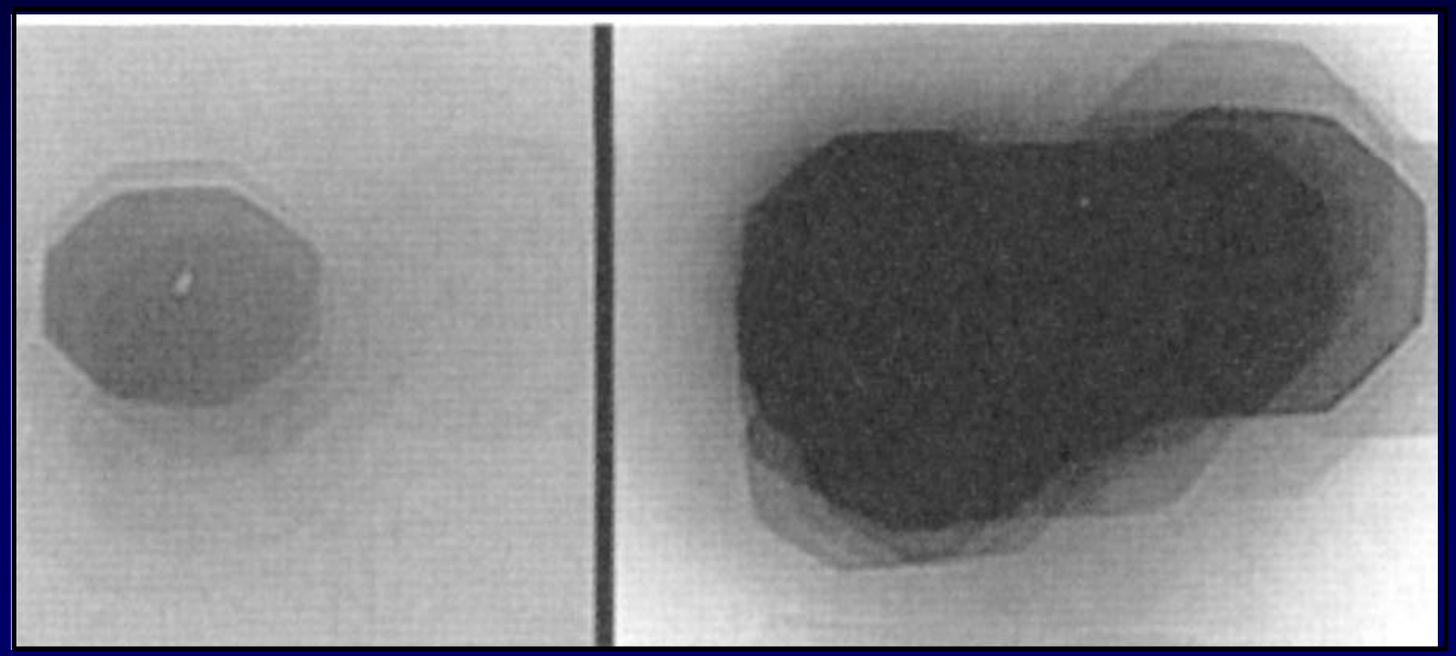


CLINICAL MEASUREMENTS

F. Other Direct Measures of Skin Dose

4. Comparison

Radiochromic Kodak EC X-ray Film



CONCLUSIONS

A. Verify Optimized Imaging Parameters

1. Image Quality will be improved
2. EERIP may be lowered
3. EER to Patient may be lowered

B. Monitor Clinical Exposures

1. Informed Proactive Risk Benefit Decisions
2. Patient Exposures Documented

C. Physicist Must Understand:

1. Imaging System Design and its Limitations
2. Clinicians and Clinical Demands