MANAGING PATIENT DOSE AND STAFF EXPOSURE IN FLUOROSCOPIC PROCEDURES

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"Our X-ray machine 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."

ACKNOWLEDGEMENTS

Phil Rauch

INTRODUCTION

A. Patient Imaging Challenges
B. Exploiting Design Features wrt Dose & Imaging
C. Scatter Radiation: Effect of Filtration
D. Operational Issues
E. Training of Operators of Fluoroscopes
F. Real Time Clinical Dose Measurements
G. Some of FDA New Rules--June 10, 2006

MANAGING PATIENT DOSE

OPERATOR & STAFF STRAY RADIATION DOSE

0.1% of Primary Radiation Dose to Patient @
1 Meter from the Primary Entrance at Patient

Total Patient Entrance Exposure

MANAGING PATIENT DOSE

Operation of Machine

Fluoroscopy Time

# of Rec Images

Total Patient Entrance Exposure

MANAGING PATIENT DOSE

Machine Design

Exposure Rate

Exposure/Image

Total Patient Entrance Exposure

MANAGING PATIENT DOSE

Machine Design

Operation of Machine

Exposure Rate

Fluoroscopy Time

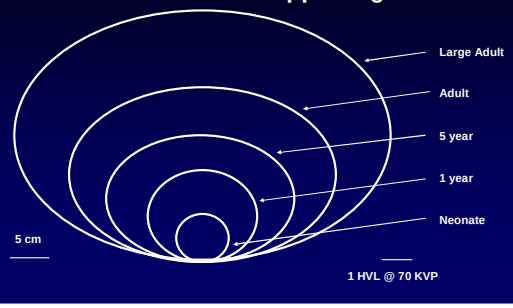
Exposure/Image

# of Rec Images

Total Patient Entrance Exposure

PATIENT IMAGING CHALLENGES

A. Patient Ages: Neonate to 21 year and Beyond or Adult Appendages!



PATIENT IMAGING CHALLENGES

B. 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!
   3. Appendages (same at LAT Projection)

PATIENT IMAGING CHALLENGES

C. Image Quality Concerns
   1. Limited Anatomical Size
      a. Magnify anatomy in image
      b. Improve High Contrast Resolution
         i. Image Processing: Edge Enhancement
         ii. Increase Matrix Size of Digital Image
         iii. Reduce Focal Spot Size
   2. Imaging Task Affects Required Dose

PATIENT IMAGING CHALLENGES

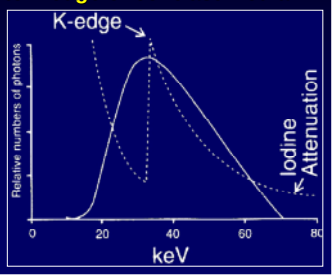
C. Image Quality Concerns
   3. Limited Subject Contrast
      a. Elevate contrast concentration
         i. Smaller Vessel diameters
         ii. Compensate with concentration

PATIENT IMAGING CHALLENGES

C. Image Quality Concerns
   3. Limited Subject Contrast
      b. Limited Injections per study
         i. Injection of chamber or great vessel: 1 cc/kg
         ii. Toxicity: 4 - 6 mL/kg of 350 mg/cc Iodine

PATIENT IMAGING CHALLENGES

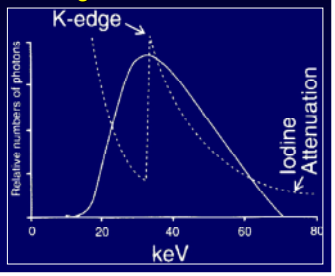
3. Limited Subject Contrast
   c. KVp matched to k-edge of contrast media
      i. 70 kVp for Standard Filtration



Balter

PATIENT IMAGING CHALLENGES

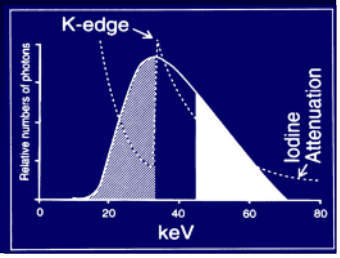
3. Limited Subject Contrast
   d. KVp matched to k-edge of contrast media
      i. 70 kVp for Standard Filtration
      ii. 55 - 60 kVp for Spectral Filtering



Balter

SPECTRAL BEAM FILTRATION

A. Change in Quality of X-ray Spectrum: Match Energy of X-rays to Absorption of Contrast Media
   1. Pass 33 - 44 keV X-rays
   2. Attenuate
      a. < 33 keV X-rays Dose
      b. > 40 keV X-rays Contrast



SPECTRAL BEAM FILTRATION

B. Required Steps
   1. Based on most recent attenuation data
      a. Add Filter
      b. Maximize Tube Current
      c. Reduce High Voltage
   2. Excessive Pulse Widths are tempting to allow use of heavier filter

PATIENT IMAGING CHALLENGES

C. Image Quality Concerns
   4. Freeze Patient Motion With Pulsed Fluoroscopy
      a. Pulse Width Ranges
         i. Pediatrics: 1 - 5 msec
         ii. Adults: 3 - 10 msec

AFFECT OF PULSE WIDTH

PW 2.4 ms
Displayed 7.5 fps

PW 7.4 ms
Displayed 7.5 fps

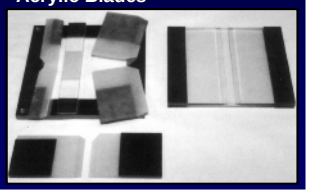
AFFECT OF PULSE WIDTH

PW 2.4 ms
Displayed 7.5 fps

PW 7.4 ms
Displayed 7.5 fps

SPATIAL BEAM SHAPING

A. Circular & Rectilinear Shutters
B. Electronic Indicators of Position
C. Equalization Filters: Attenuation Compensation
   1. Linear & Rotational Movement
   2. Shaped Tapered Lead - Acrylic Blades
   3. Interchangeable
   4. Less Integral Dose
D. Tight Collimation
   1. Scatter Reduced
   2. Less Integral Dose



PATIENT IMAGING CHALLENGES

D. Patient Doses Below 70 kVp Are Excessive
   1. Newborn (Appendage) Fluoro Frame
      a. 70 kVp & 0.01 mAs: 0.046 mR
      b. 45 kVp & 0.08 mAs: 0.20 mR
   2. Newborn (Appendage) Cath Frame
      a. 70 kVp & 0.1 mAs: 0.48 mR
      b. 45 kVp & 0.8 mAs: 2.0 mR
   3. Newborn (Appendage) DSA Recorded Image
      a. 70 kVp & 3 mAs: 14 mR
      b. 45 kVp & 24 mAs: 110 mR

MANAGING PATIENT DOSE

MACHINE DESIGN

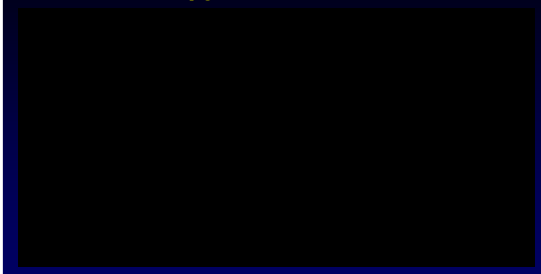
Exposure Rate

Exposure/Image

Total Patient Entrance Exposure

VARIABLE RATE PULSED FLUOROSCOPY

Fluoroscopy – Pulsed vs. Continuous

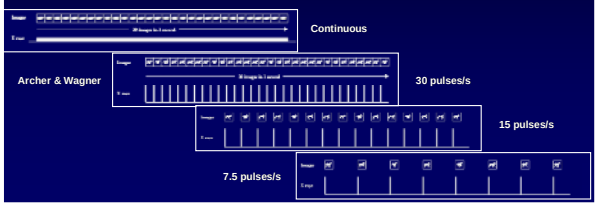


Pulsed Fluoro - 30pps
(Displayed at 7.5 fps)

Continuous Fluoro
(Displayed at 7.5 fps)

GENERATOR CONTROLS

A. Variable Rate Pulsed Fluoroscopy
   1. Image Quality vs Radiation Dose
      a. Proper Pulse Rate Balances Temporal Information Loss vs Patient Dose

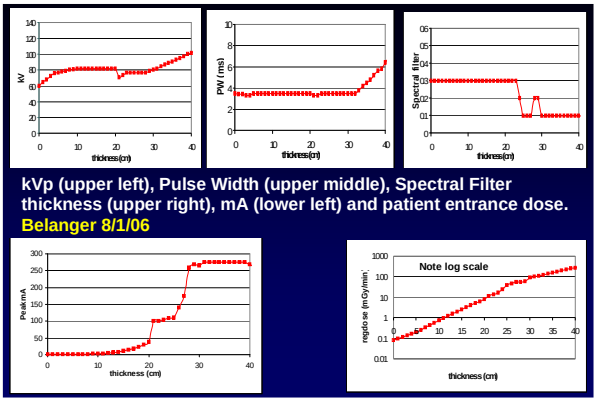


GENERATOR CONTROLS

A. Variable Rate Pulsed Fluoroscopy
   2. Tube Current
      a. Minimum: 10 mA
      b. Maximum: 100 mA
   3. Limited Range High Voltage
      a. Std Filtration: ~ 70 kV
      b. Spectral Filtration: ~ 55 - 70 kV

GENERATOR CONTROLS

A. Variable Rate Pulsed Fluoroscopy
   4. Preferred Modulation of Technique Factors
      a. Starting Values
         i. 65 - 70 kVp
         ii. 3 msec
      b. Modulation Hierarchy
         i. Tube Current
         ii. Pulse Width (limited range)
         iii. High Voltage



kVp (upper left), Pulse Width (upper middle), Spectral Filter thickness (upper right), mA (lower left) and patient entrance dose.
Belanger 8/1/06

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure (IRE)

1. Operator Selectable: Task Oriented
   a. Low (Half of Normal)
   b. Normal
   c. High (Double of Normal)
2. Beware of Marketing Strategies
   a. Two level systems
   b. "Machine cuts exposure in half"
      i. Relative to what?

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Exposure

3. What should "NORMAL" IRE be?
   a. No Absolute Standard
      i. Imaging Task
      ii. Equipment Design
      iii. Operator Preference?
   b. Structure Other Exposures Relative to "Normal"
   c. Acceptance Test Machine to Verify Structured Exposure Values

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure

3. What should "Normal" be?
   d. Minimum IRE
      i. Good Image Quality
      ii. Diameter of Vessel to Image
      iii. Contrast Concentration in Vessel
      iv. IRE α $1 / p^2c^2D^2$
         p = precision
         c = concentration of contrast
         D = diameter of vessel
      v. Reduced Perceived Noise (p^2) Improves IQ

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   3. What should "Normal" be?
      e. Maximum IRE
         i. Perceived Noise Determined by System Noise
         ii. System Noise = $[QM^2 + EN^2]^{0.5}$
             QM = Quantum Mottle
             EN = Electronic Noise
         iii. Want QM > EN
         iv. Excessive IRE Degrades Image Quality for large patients

CONTROL OF IMAGE RECEPTOR EXPOSURE

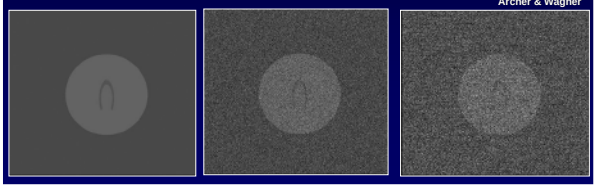
23 cm FOV @ 80 kVp
Standard Filtration
30 Pulses per Second

Operational Mode	Normal IRE Range (nGy/p)
Standard Fluoro (II)	15
Standard Fluoro (Flat Panel)	25 - 35
Digital Angiography	450 - 900
Digital Subtraction Angio	4,500 - 9,000
Cardiac Digital	100 - 150

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   4. Reduced Variable Rate Pulsed Fluoroscopy
      a. Reasons for Rejection
         i. Temporal Resolution Loss
         ii. Increase in Perceived Noise

Archer & Wagner



CONTROL OF IMAGE RECEPTOR EXPOSURE

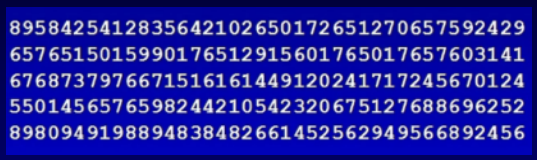
B. Image Receptor Entrance Exposure
   4. Variable Rate Pulsed Fluoroscopy
      b. Increased Perceived Noise With Decreased Pulse Rates,

NOT LOSS OF TEMPORAL RESOLUTION

is the Primary Cause of Rejection of Low Pulse Rate Fluoroscopy

Noise - Random

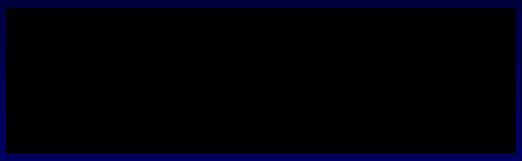
Where are the 3's?



30 Frames/sec

Noise - Random

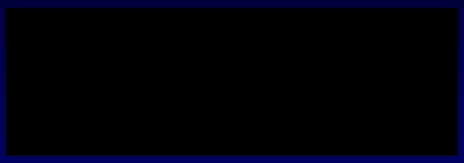
Where are the 3's?



15 Frames/sec

Noise - Random

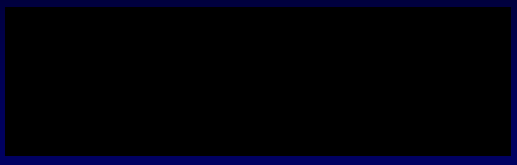
Where are the 3's?



8 Frames/sec

Noise - Random

Where are the 3's?



4 Frames/sec

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   4. Variable Rate Pulsed Fluoroscopy
      c. Structured Exposures Relative to "Normal"
         i. IRE / Frame α $(30/\text{Pulse Frequency})^{1/2}$
            - Less frame integration by eye
            - IRE / Frame Increased as Pulse Rate Decreases
            - Introduces ALARA vs ALAP!

PERCIEVED NOISE PHANTOM

Rotating Gear
HC Motion

Uniform Background
Perceived Noise

Spring
LC Motion

Baby Ben Travel Alarm by Westclock

AUFRICHTIG PRINCIPLE

IR Exp/frame = X

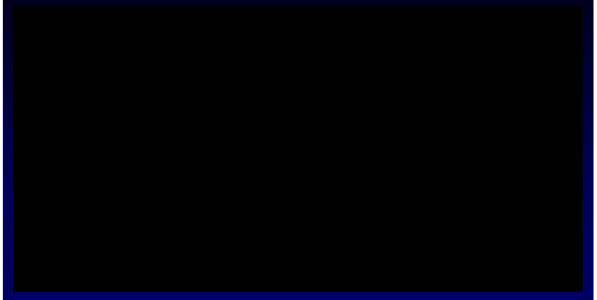
Patient Exp Rate Reduced 4X

AUFRICHTIG PRINCIPLE

IR Exp/frame = X vs 2X

Patient Exp Rate Reduced 2X

AUFRICHTIG PRINCIPLE



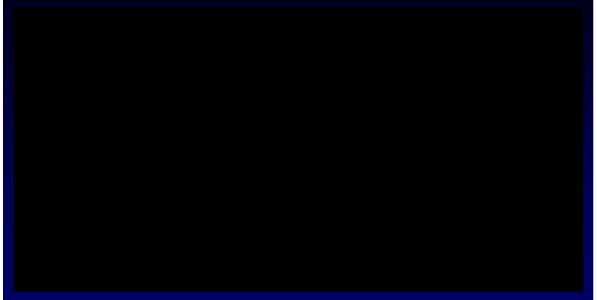
IR Exp/frame = X vs 2X Patient Exp Rate Doubled

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   4. Variable Rate Pulsed Fluoroscopy
      c. Structured Exposures Relative to "Normal"
         i. EERIR/Frame α (30/Pulse Frequency)$^{1/2}$
         ii. New relationship for < 7.5 pulses/sec

Exposure/Frame α Constant

AUFRICHTIG PRINCIPLE



IR Exp/frame = 2X Patient Exp Rate Reduced 7.5X

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   5. Structured Exposures Relative to "Normal"
      a. "Spectral Beam" Filtering
         i. Greater Effective Energy of Beam
         ii. Less X-rays @ same Exposure
         iii. Quantum Mottle Increases
         iv. Double Exposure wrt Standard Filtration
            – ALARA vs ALAP!

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   5. Structured Exposures Relative to "Normal"
      b. Function of FoV Change
         i. Old equipment with fixed apertures
            – Exposure α 1/FoV^2
            – Exposure Rate Quadruples with a 11 cm FoV vs a 22 cm FoV
            – Excessive Patient Dose

CONTROL OF IMAGE RECEPTOR EXPOSURE

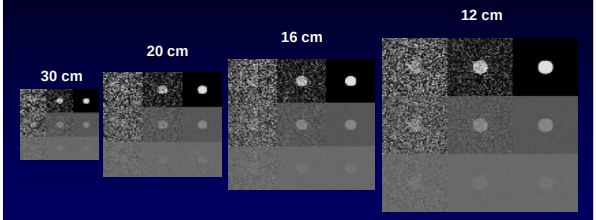
B. Image Receptor Entrance Exposure
   4. Structured Exposures Relative to "Normal"
      b. Function of FoV Change
         ii. Newer equipment with image intensifiers
            – Exposure α 1/FoV
            – Exposure Rate Doubles with a 11 cm FoV vs a 22 cm FoV
            – Exposure increase reduces perceived noise in a sharper image
            – ALARA

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure
   4. Structured Exposures Relative to "Normal"
      b. Function of FoV Change
         iii. New equipment with flat plate detectors
            – Exposure α Constant
            – Exposure Rate Unchanged with a 11 cm FoV vs a 22 cm FoV
            – Sharpness Primarily Determined by Size of Plate's Pixels, not Size of FoV
            – Small vs Large Plates
            – ALARA or ALAP?

Options for Dose Change with Field of View

Illustration of FOV Change without Dose Change



How much does IQ improve with magnification alone?

CONTROL OF IMAGE RECEPTOR EXPOSURE

B. Image Receptor Entrance Exposure

5. Structured Exposures Relative to "Normal"

a. IRE/Fr = $IRE/FR_N * (30 / Pulse\ Frequency)^{1/2}$

b. $IRE_{spectral\ filter} = 2 \times IRE_N$

c. IRE(FoV) α 1/FoV (Image Intensifier)

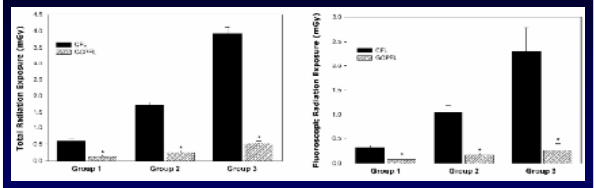
d. IRE(FoV) α Constant (Flat Plate)

e. $1/2 \times IRE_{high} = IRE_{normal}$

f. $IRE_{normal} = IRE_{low} \times 2$

ANIMAL VCUG STUDY RESULTS

Ward VL, Barnewolt CE, Strauss KJ, et.al. *Radiology* 2006; 238: 96-106.



Total Radiation Exposure | Fluoroscopic Radiation Exposure

7 - 10 Fold Reduction in Skin Entrance KERMA

CLINICAL VCUG STUDY

A. Effective Dose for Small Child (8 - 8.5 cm girth)

1. Pulsed Fluoro (69 µGy) ~ 10x > RNC (6 µGy)
2. Con Fluoro (590 µGy) ~ 100 x > RNC (6 µGy)

B. Estimated Risks:

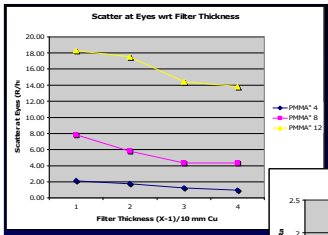
1. Pulsed Fluoro ~ 8 days Bkg Radiation
2. Con Fluoro ~ 68 days Bkg Radiation
3. RNC < 1 day of background radiation

Scatter Measurements at Operator's Eyes

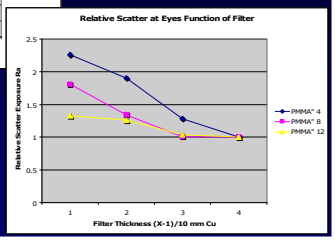
Grid In

40 cm Field of View

Continuous Fluoroscopy



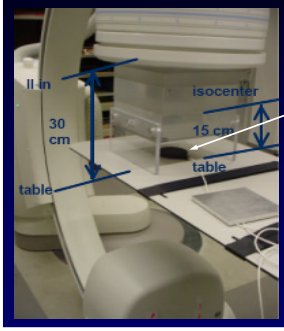
Scatter Measurements at Operator's Eyes



Scatter **Increases**:
- > 125% for 4" PMMA
- < 30% for 12" PMMA

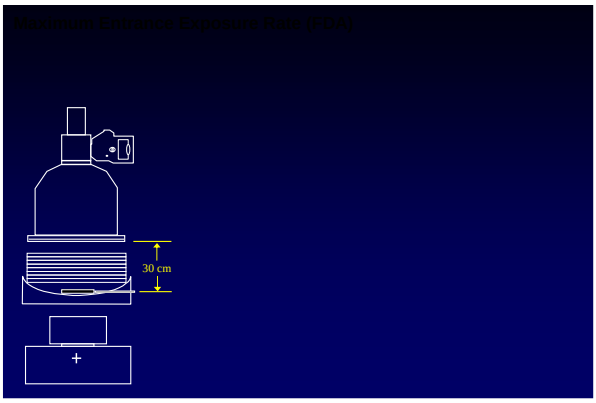
As Filter Decreases to No **Added** Filter

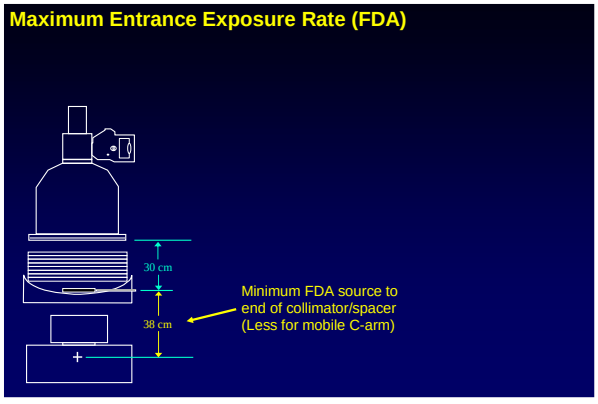
MEASUREMENT OF MAX ESE

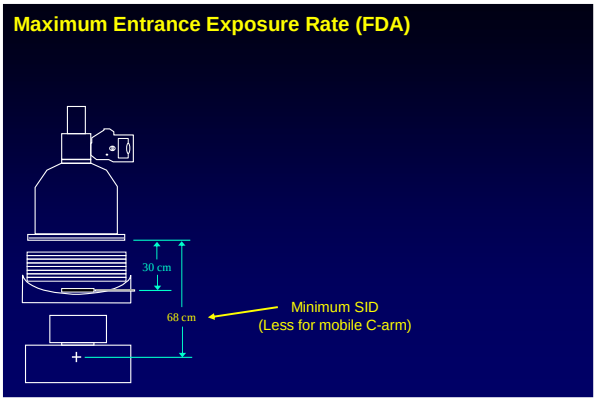


Ion chamber is at the FDA measurement point for maximum entrance exposure rate, AND at the Interventional Reference Point (IEC standard 60601-2-43).

These two measurement points are not always at the same location in space.


Maximum Entrance Exposure Rate (FDA)
30 cm
+

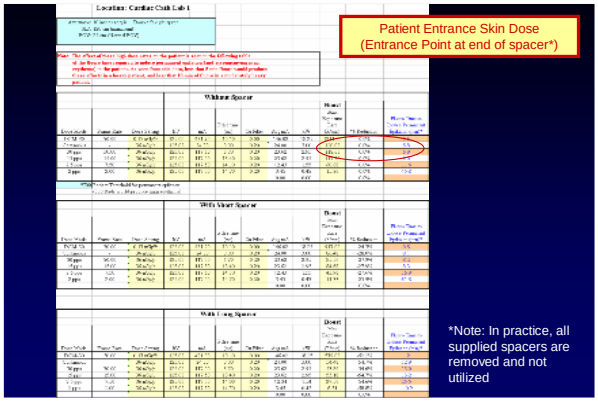

Maximum Entrance Exposure Rate (FDA)
30 cm
38 cm
Minimum FDA source to
end of collimator/spacer
(Less for mobile C-arm)
+


Maximum Entrance Exposure Rate (FDA)
30 cm
68 cm
Minimum SID
(Less for mobile C-arm)
+

Case of the disappearing spacer

Case of the disappearing spacer

Case of the disappearing spacer



Patient Entrance Skin Dose
(Entrance Point at end of spacer*)

*Note: In practice, all supplied spacers are removed and not utilized

MANAGING PATIENT DOSE

OPERATION OF MACHINE

- Fluoroscopy Time
- # of Rec Images

Total Patient Entrance Exposure

RISK/BENEFIT ANALYSIS

A. Questions that **MUST** be Answered:
   1. Will the requested exam answer the clinical question?
   2. Could a nonionizing imaging modality answer the question in all or some instances?
   3. Does the benefit of the ionizing exam outweigh the associated risk(s)?

B. Canceling the ionizing exam is the **maximum ALARA** step that can be achieved!

CONTROL OF IMAGE RECEPTOR EXPOSURE

C. Anatomical Program Selections Control
   1. Acquisition Parameters
      a. Focal Spot Size
      b. kVp, tube current, pulse width, pulse rate, etc.
      c. Image Receptor Entrance Exposure
   2. Image Processing Parameters
      1. Edge Enhancement
      2. Frame Integration (Noise Smoothing)
      3. Many Others

CONTROL OF IMAGE RECEPTOR EXPOSURE

C. Anatomical Program Selections Control

3. NEED TAILORED SELECTIONS
   1. Girth based
   2. Limit range of girths for a given set of technique factors

4. Do Not Assume Vendor Understands These Requirements

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. Who?
1. Fluoroscopic Operators
   a. All non Radiologists
   b. All Radiologists
2. Technologists Should Reinforce Principles
3. Modified for
   a. Nurses
   b. Anesthesiologists
   c. Other Support Personnel in Procedure Room

TRAINING OF STAFF

C. What Type of Training?
1. Training Provided at Regular In-Services
   a. Basic Imaging Principles
   b. Radiation Protection Principles
2. "Buttonology": Unique Operational Features of Imaging Equipment

TRAINING OF STAFF

C. What Type of Training?
   3. Formalized Credentialing Program for all Fluoroscopic Users
      a. Didactic Lectures
      b. Competency Exam
      c. Hands-On Machine Training Competency

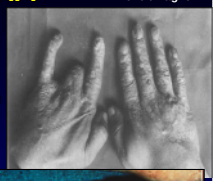
TRAINING OF STAFF

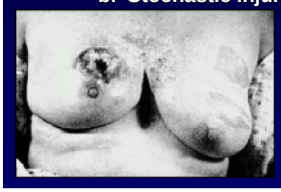
D. Administrative Issues
   1. Approved at Highest Possible Administrative Level
   2. Annual or Bi-Annual Renewal
   3. Avoid "Grandfathering"?
   4. Credentials from Another Institution?
   5. Web data base of credentialed users

TRAINING OF STAFF

E. Didactic Lectures
   1. Radiation Quantities & Units
   2. Biological Effects of Radiation
      a. No Warning Sensation
      b. Stochastic Injuries

Archer/Wagner





TRAINING OF STAFF

E. Didactic Lectures
   2. Biological Effects of Radiation
      b. Stochastic Injuries
      c. Deterministic Injuries
         1. Threshold/Latent Periods

Archer/Wagner

TRAINING OF STAFF

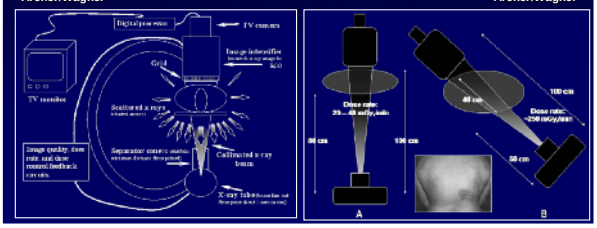
E. Didactic Lectures

3. Techniques that

a. Improve Image Quality

b. Reduce Radiation Dose

Archer/Wagner



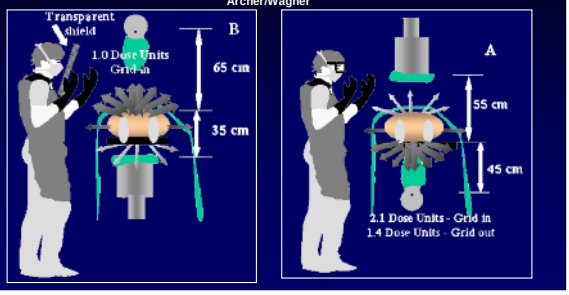
Archer/Wagner

TRAINING OF STAFF

E. Didactic Lectures

5. Provide Practical Examples: Personnel Positioning

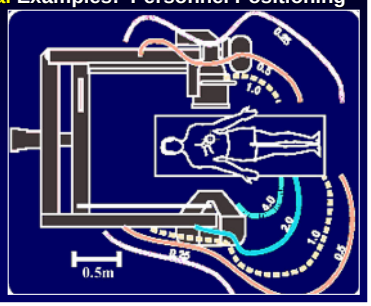
Archer/Wagner



TRAINING OF STAFF

E. Didactic Lectures

5. Provide Practical Examples: Personnel Positioning



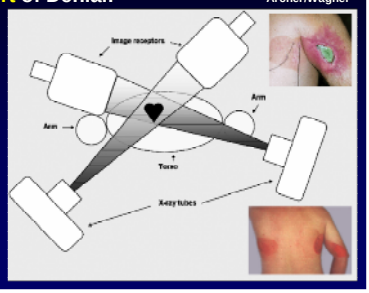
Balter

TRAINING OF STAFF

E. Didactic Lectures

4. Shatter Comfort of Denial!

Archer/Wagner

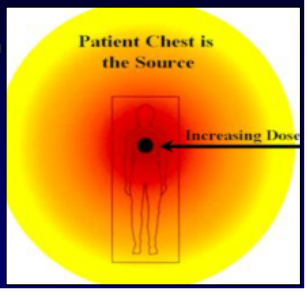


TRAINING OF STAFF

F. Competency Exam
   1. Multiple Choice Exam
      a. Web based?
      b. Practical applications of topics
         i. Didactic Lecture
         ii. Web based Curriculum
   2. Other Format?

TRAINING OF STAFF

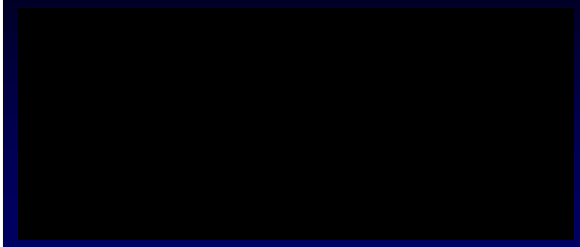
G. Hands-On Machine Training
   1. One on One
   2. Proper manipulation of each control
   3. Checklist for each machine
   4. "Chirpie"



TRAINING OF STAFF

G. Hands-On Machine Training
   1. Last-Image-Hold
      a. Last Video Frame of Fluoro Continuously displayed after release of Fluoro
      b. High Perceived Noise
   2. Fluoro Store Mode
      a. Store Fluoroscopic Video Frame on Disc
         i. Higher Perceived Noise
         ii. Less Patient Dose than Recorded Image

LIH vs. LIVE FLUORSCOPY



Low Dose (No Frame Integration)

Low Dose (Maximum Frame Integration)

TRAINING OF STAFF

G. Hands-On Machine Training
   3. Last-Fluoro-Loop Playback/Store
      a. Last 10 second sequence of Live Fluoro displayed in repeatable loop after release of Fluoroscopy
      b. No loss of image quality
      c. Images can be archived
      d. Teaching Aid
      e. Downside: Fill up of hard disc storage

REAL TIME DOSE INFORMATION FOR THE FLUOROSCOPIC OPERATOR

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

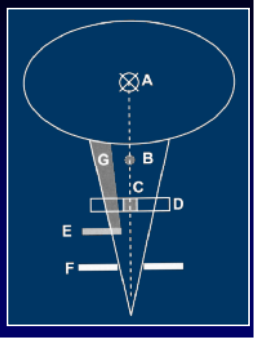
Balter S, Shope TB, Fletcher DW, Kuan HM, Seissl H. "Techniques to Estimate Radiation Dose to Skin During Fluorosopically Guided Procedures"
2002 AAPM Summer School Proceedings

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. DAP
      a. Isocenter
      b. Dose Reference Point
      c. KERMA chamber
      d. DAP chamber
      e. "Wedge" Filter
      f. Collimator Blade
      g. Reduced Dose Area

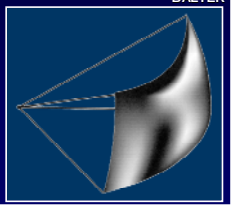


BALTER

CLINICAL MEASUREMENTS

D. Cumulative Dose
   2. Dose-Area-Product (DAP)
      a. Integral of Dose Across Entire Beam
      b. Indication of Integral Dose--Stochastic Risk
      c. No Table Top Attenuation Correction
      d. Inaccurate Skin Dose

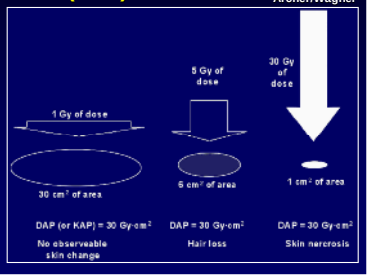
BALTER



CLINICAL MEASUREMENTS

D. Cumulative Dose
   2. Dose-Area-Product (DAP)
      e. Can not predict risk of deterministic injury

Archer/Wagner

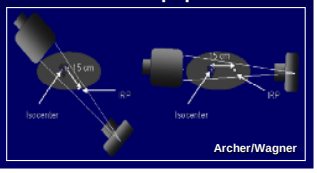


CLINICAL MEASUREMENTS

D. Cumulative Dose
   3. Calculated Patient Exposure
      a. PEMNET®
         i. Advantages
            - 5% Accuracy
            - Database Provided
            - Real-Time Displays
         ii. Disadvantages
            - Additional Cabling
            - Noise Free Interfaces
            - Involved Calibration
            - Database Maintenance

CLINICAL MEASUREMENTS

D. Cumulative Dose
   4. Current Cumulative Skin Dose Approach
      a. Entrance Dose at International Reference Point defined by IEC
      b. IRP 15 cm toward focal spot from isocenter
      c. Mandated by CDRH on New Equipment
   5. Future
      a. DICOM Dose
      b. Header Modifications for Fluoroscopy

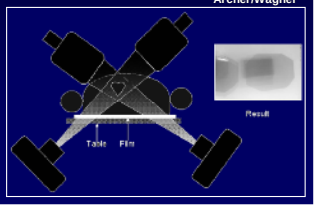


Archer/Wagner

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 Port
         i. On-Time
         ii. Patient Size
         iii. Beam Orientation
      c. Overlap of Ports

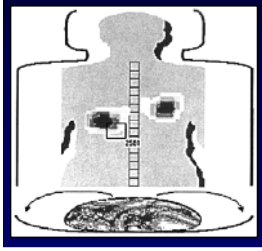
Archer/Wagner



CLINICAL MEASUREMENTS

E. Peak Skin Dose
   2. Derived Patient Exposure
      a. CareGraph®

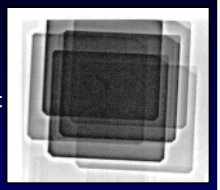
Balter



      iii. Disadvantages
         - No Longer Available
         - Skin Modeled to One Standard Adult Body
      iv. Advantages
         - More Flexible than Film

CLINICAL MEASUREMENTS

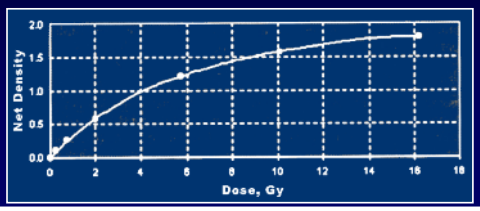
E. Peak Skin Dose
   3. X-Ray Film Dosimetry
      a. Advantages
         i. Dose Distribution
         ii. Universal with any Unit
         iii. Quantitative Dose Info
      b. Disadvantages
         i. Limited Range
         ii. Factors Affecting Film Sensitivity
         iii. Positioning wrt to the patient
         iv. No Real-Time Feedback


Balter

CLINICAL MEASUREMENTS

E. Peak Skin Dose

4. Radiochromatic Film (GAFCHROMIC XR-Type R)
   a. Chemical Radiation Sensors that Change Color in Response to Exposure



CONCLUSIONS

A. Imaging Equipment Needs to be Configured for

1. Wide dynamic range of mAs
2. Freeze patient motion with short pulse widths
3. Carefully control subject contrast with limited range of kVp
4. Balance image quality needs against increased patient radiation dose with proper entrance exposure to image receptor.

CONCLUSIONS

B. Imaging Equipment Must be Both:

1. Acceptance Tested &
2. Commission Tested

C. Operational Issues Must be Addressed:

1. All users must be trained
   a. Core Knowledge
   b. Equipment Specific Controls
   c. Real Time Patient Dose Information
2. Risk/Benefit to Patient evaluated realtime