Protocol Review and Optimization: Optimization of Pediatric DR

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Introduction

- Some challenges
- Resources that assist with pediatric imaging
- Sorry state-of-the-practice
- Equipment modifications for pediatric imaging
  - Grid issues
  - AEC issues
- Operational issues
  - Measuring patient size
  - A structured program/Necessary support
- Do you have what it takes to take on the OPERATIONAL issues?

Fact

- Vast majority of imaging equipment sold is to **adult** facilities,

BUT

- Sooner or later **almost all** these units will perform some **pediatric** imaging.

Fact

- Imaging equipment is quite well
  - Designed and
  - Configured[1]

  'out of the box' for imaging adult patients.

BUT

- The same can not be said about configurations for pediatric imaging!
- Some necessary configurations may not exist!

[1]Insuring the use of design strengths while compensating for design weaknesses for a specific size patient and imaging task.

THE Question

- Why should your
  - Son or Daughter
  - Niece or Nephew
  - Grandson or Granddaughter

  receive less care[2] during imaging than that received by their parents, uncle or aunt, or grandparents?

[2]Properly managed radiation dose and image quality as a function of patient size.

Fact

- I can purchase imaging equipment from a number of companies who make quality units —in all cases images will be produced,

BUT

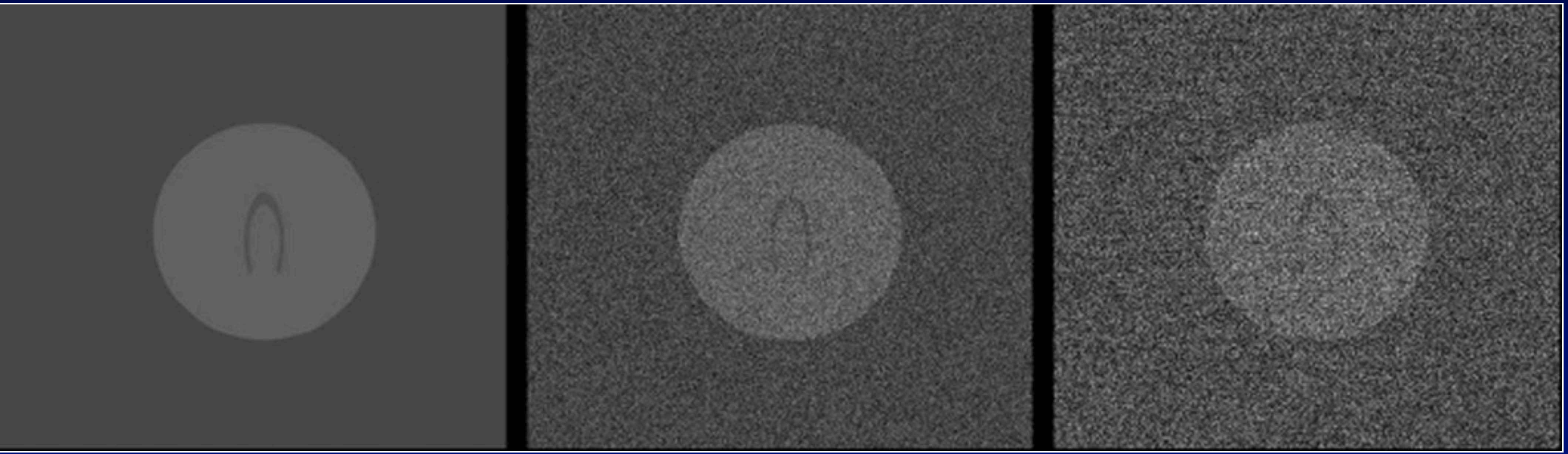
- In addition to the equipment I want a collegial ‘relationship’ to work within to optimize equipment performance for my clinical task.

MANAGING PATIENT DOSE

Sufficient Dose to detector to manage Quantum Mottle in the image

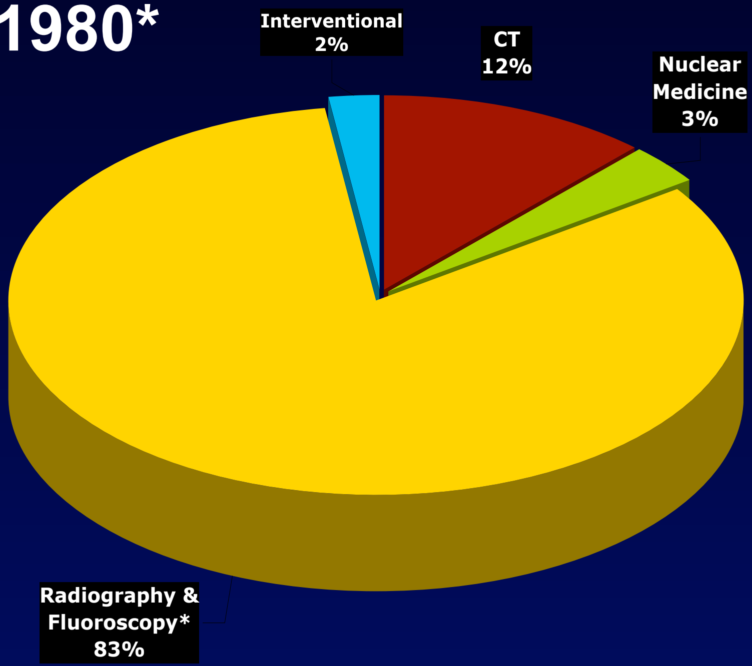
- Dose directly affects quantum mottle
- Lack of sharpness and contrast in the image results in poor image quality despite higher doses.

Archer & Wagner



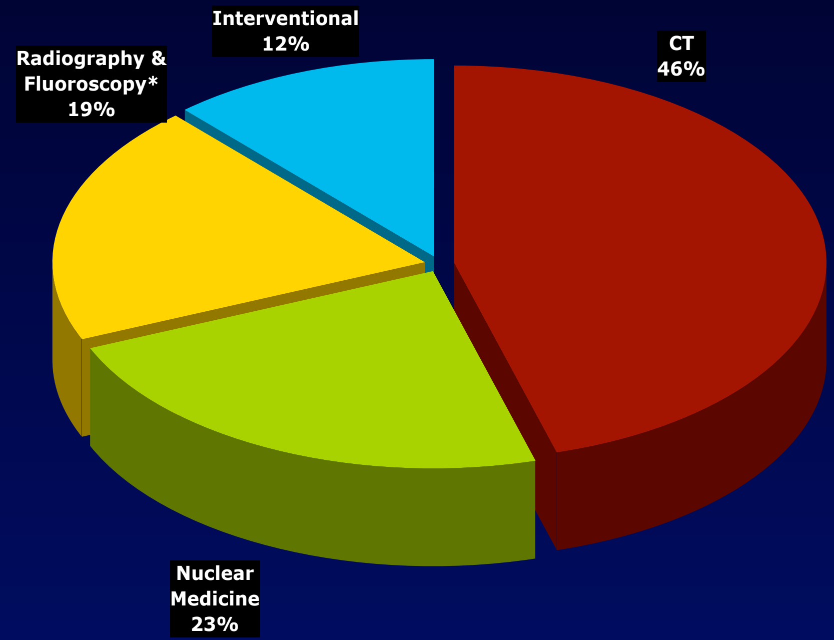
Procedures vs Effective dose contributions

US 1980*



Percent Procedures

US 2006

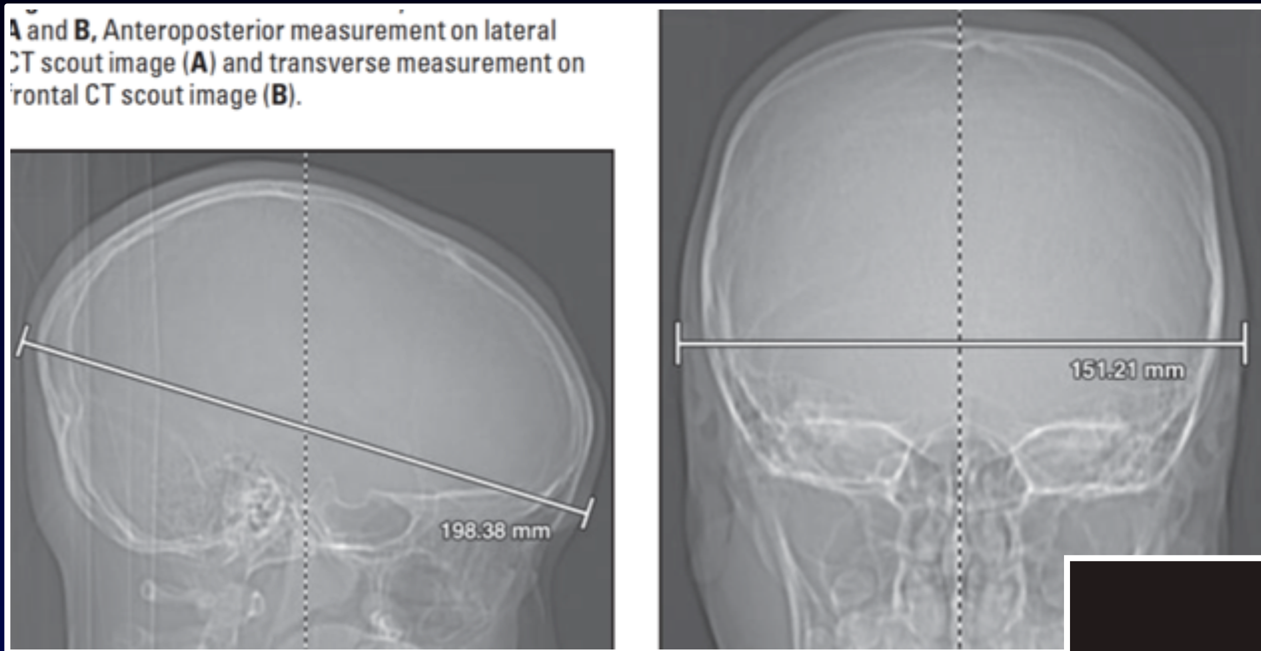


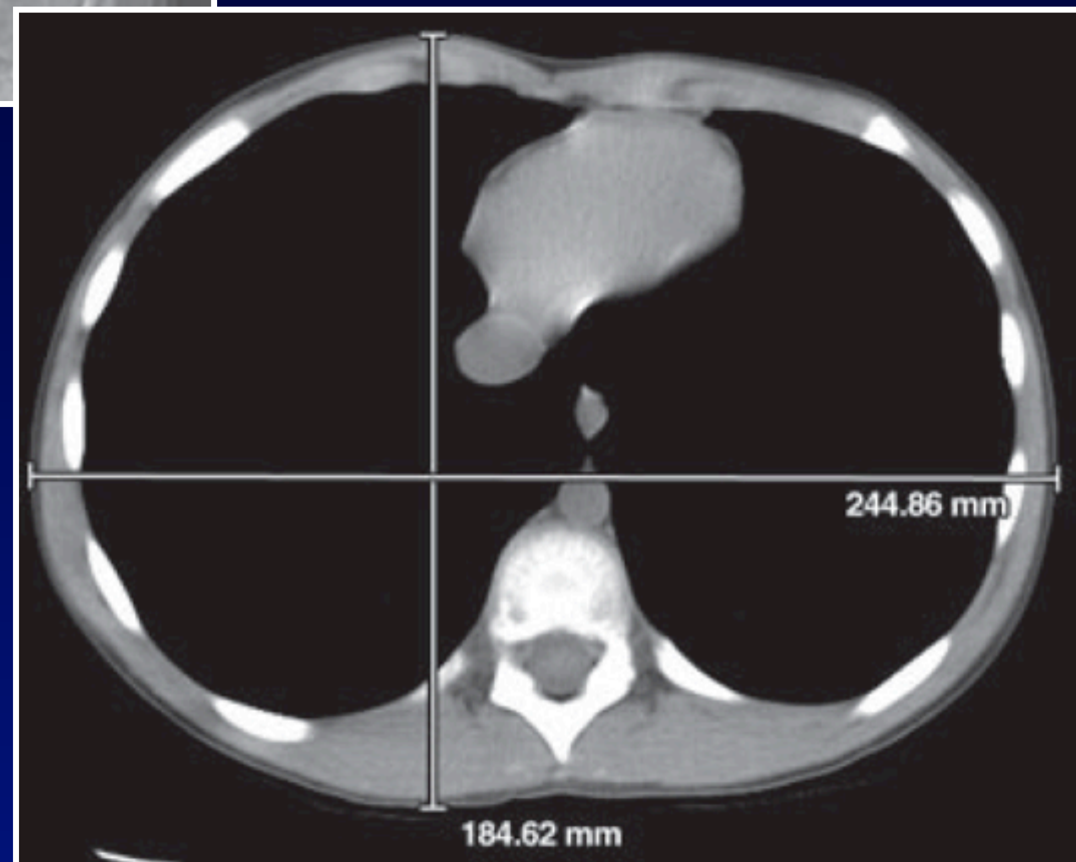
Effective Dose Contributions

17% of All Exams Deliver 81% of Total dose

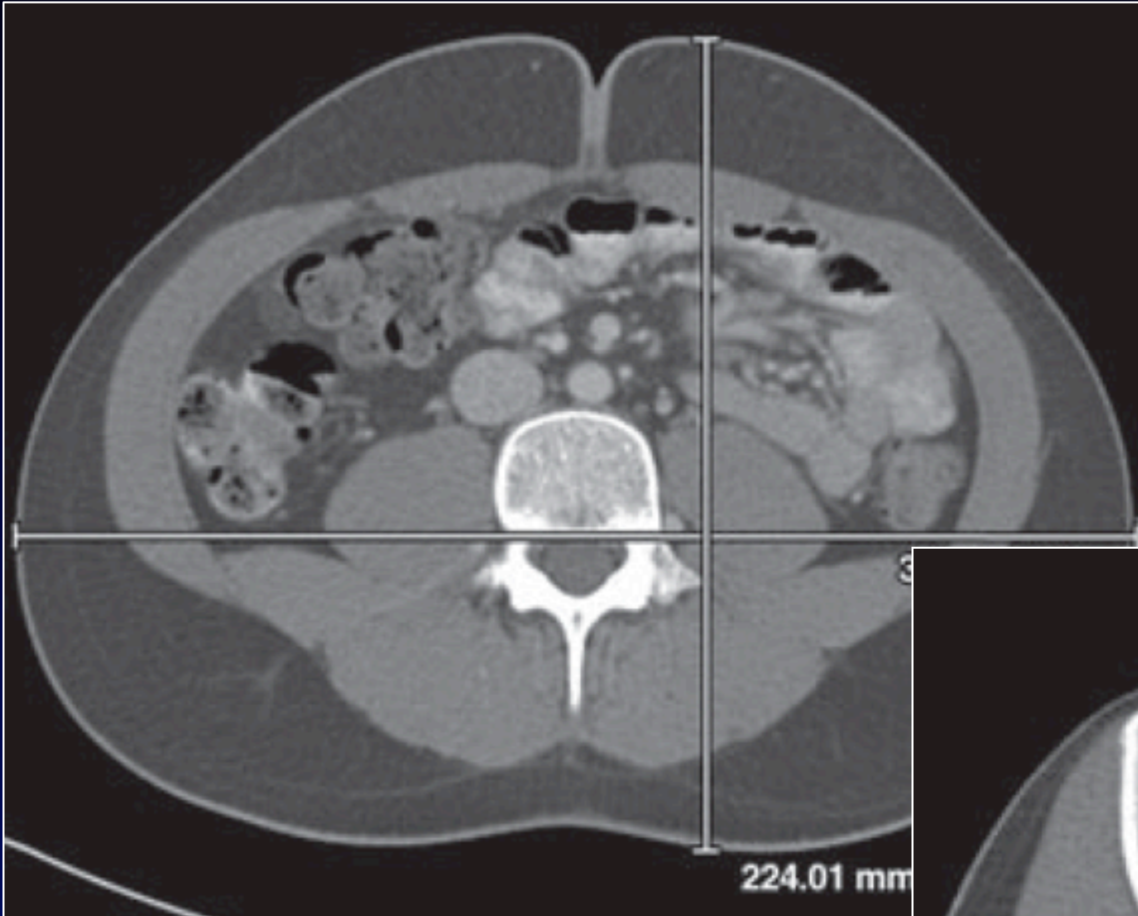
*** NCRP 93**

Adapted from Mahesh





Kleinman PL, et. al. Patient size …
AJR 194, June 10, pp. 1611 – 1619.



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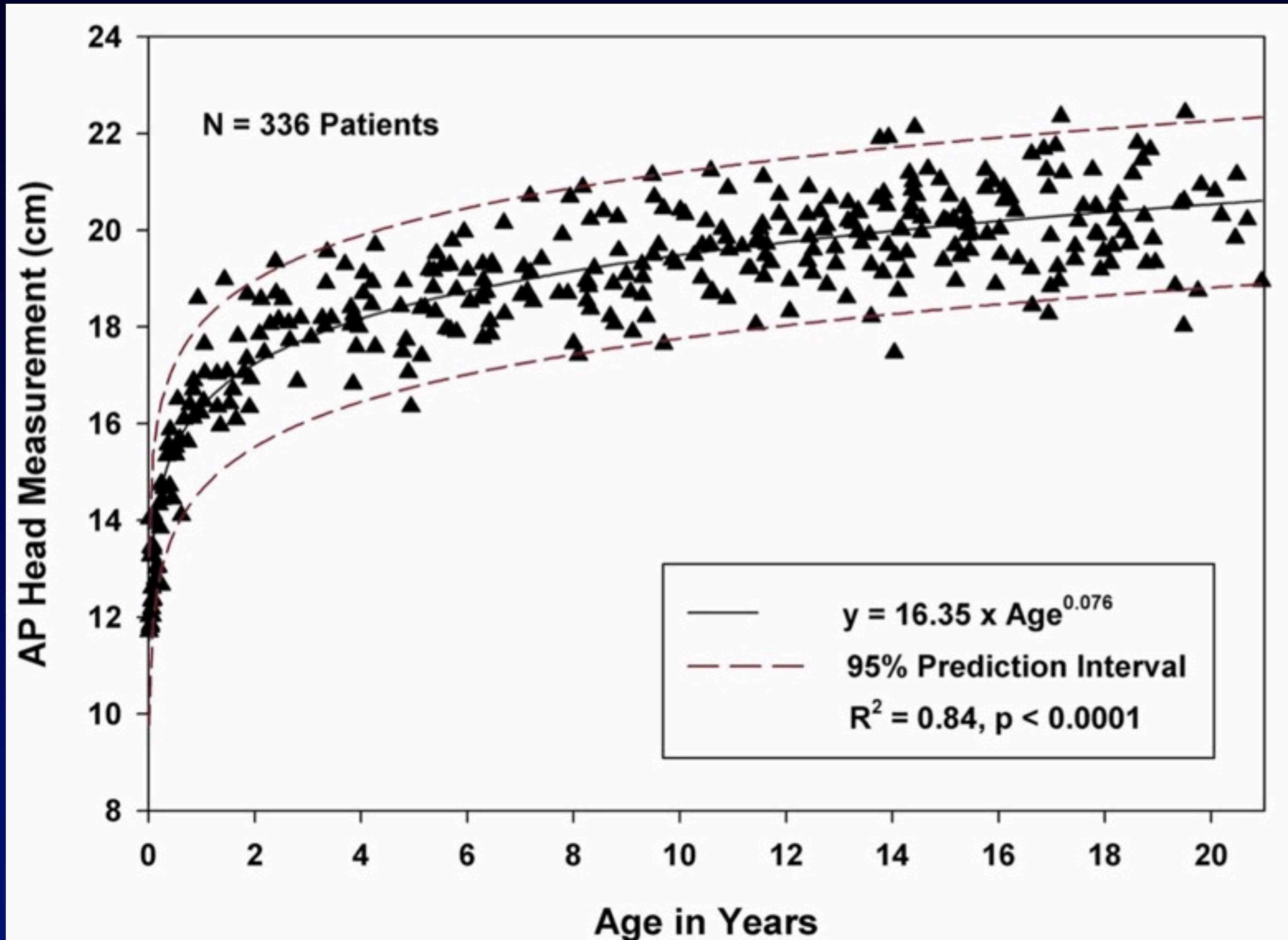
PEDIATRIC IMAGING CHALLENGES



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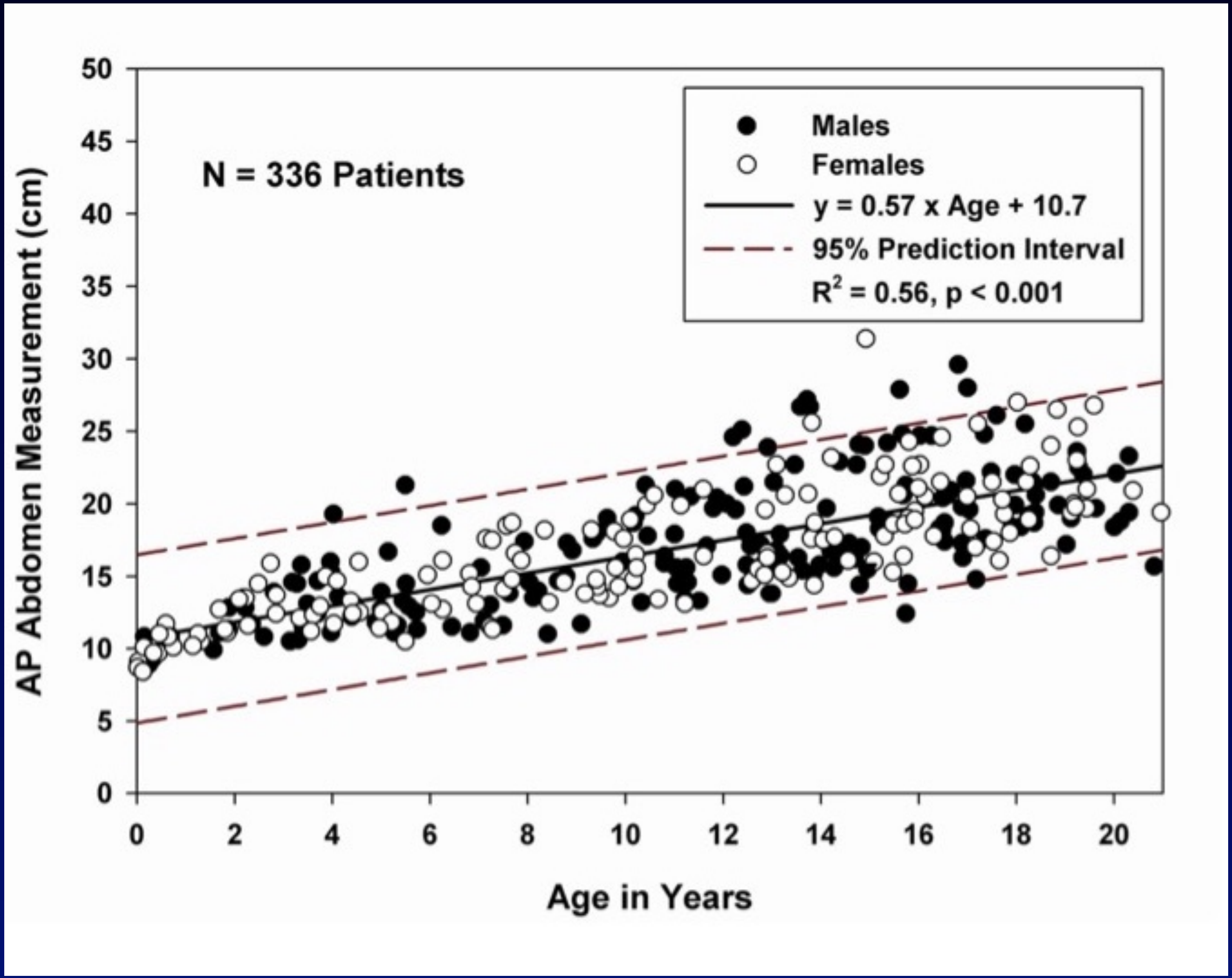
PEDIATRIC IMAGING CHALLENGES



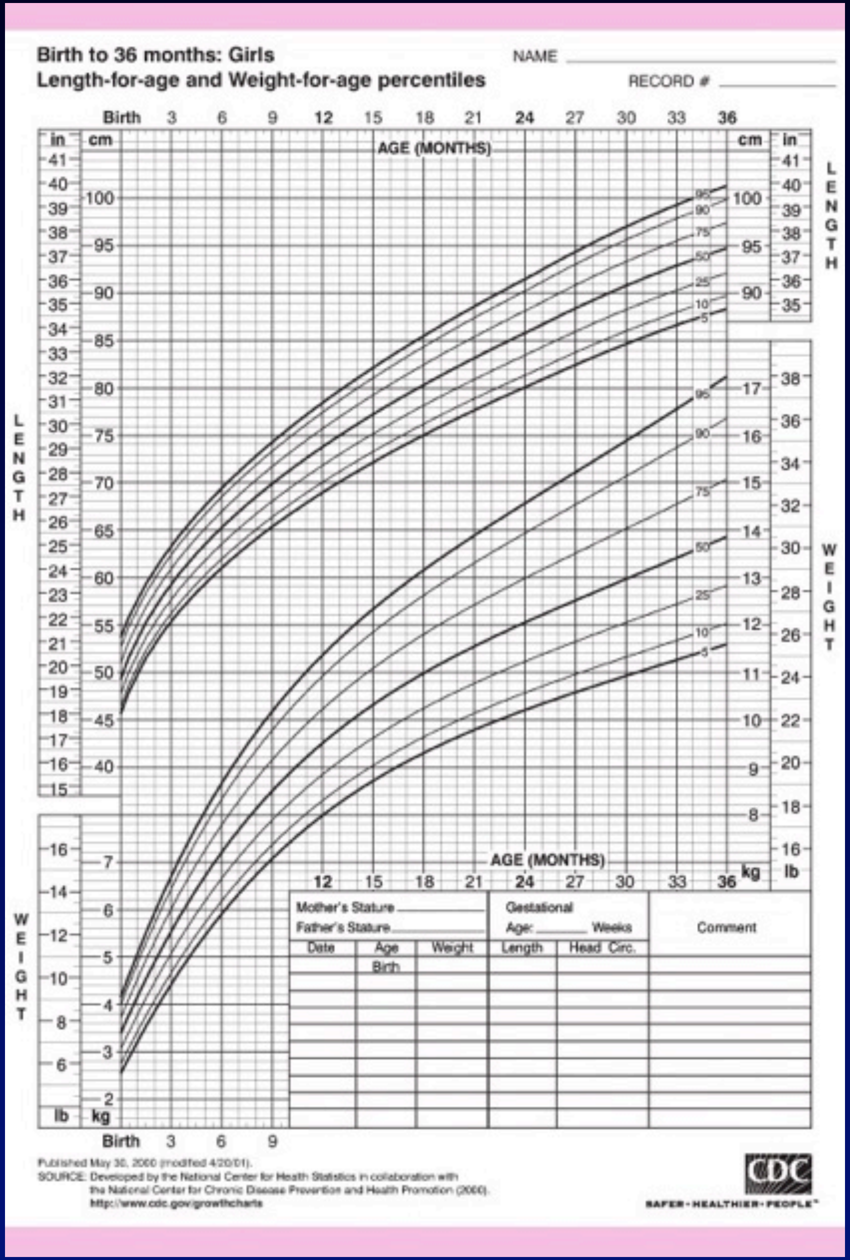
Kleinman PL, et. al. Patient size … AJR 194, June 10, pp. 1611 – 1619.

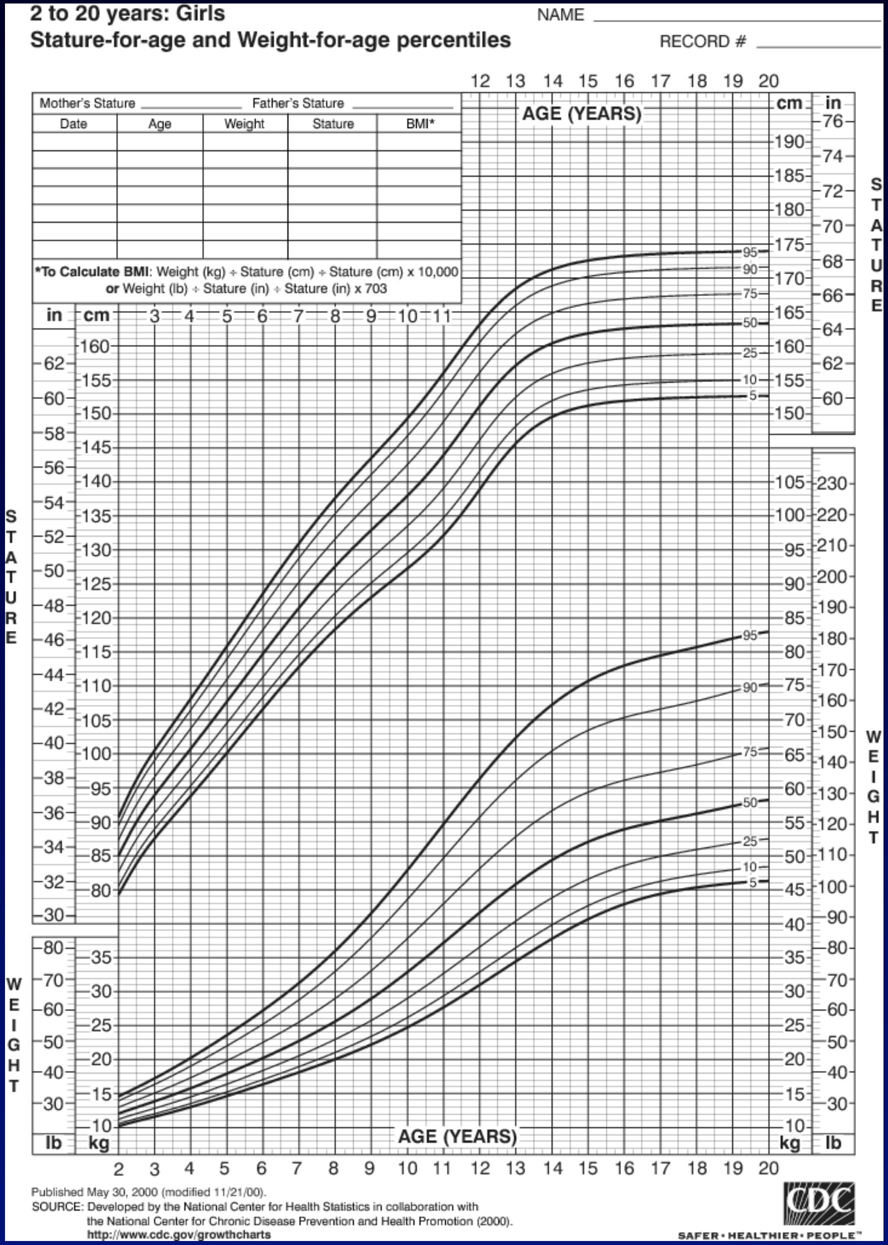
PEDIATRIC IMAGING CHALLENGES

	Anteroposterior Measurement (cm)			Transverse Measurement (cm)		
		95% Prediction Interval			95% Prediction Interval	
Age (y)	Mean	Lower	Upper	Mean	Lower	Upper
Abdomen						
0.5	11.0	5.2	16.8	15.4	7.4	23.4
1	11.2	5.4	17.0	15.9	7.9	23.9
2	11.8	6.0	17.6	16.8	8.9	24.8
3	12.4	6.6	18.2	17.8	9.8	25.7
4	12.9	7.2	18.7	18.7	10.7	26.7
5	13.5	7.7	19.3	19.6	11.7	27.6
6	14.1	8.3	19.9	20.6	12.6	28.5
7	14.7	8.9	20.4	21.5	13.5	29.4
8	15.2	9.5	21.0	22.4	14.5	30.4
9	15.8	10.0	21.6	23.4	15.4	31.3
10	16.4	10.6	22.1	24.3	16.3	32.2
11	16.9	11.2	22.7	25.2	17.3	33.2
12	17.5	11.7	23.3	26.2	18.2	34.1
13	18.1	12.3	23.8	27.1	19.1	35.0
14	18.6	12.9	24.4	28.0	20.1	36.0
15	19.2	13.4	25.0	28.9	21.0	36.9
16	19.8	14.0	25.6	29.9	21.9	37.8
17	20.4	14.6	26.1	30.8	22.9	38.8
18	20.9	15.1	26.7	31.7	23.8	39.7
19	21.5	15.7	27.3	32.7	24.7	40.6
20	22.1	16.3	27.9	33.6	25.6	41.6

Kleinman PL, et. al. Patient size … AJR 194, June 10, pp. 1611 – 1619.

PEDIATRIC IMAGING CHALLENGES

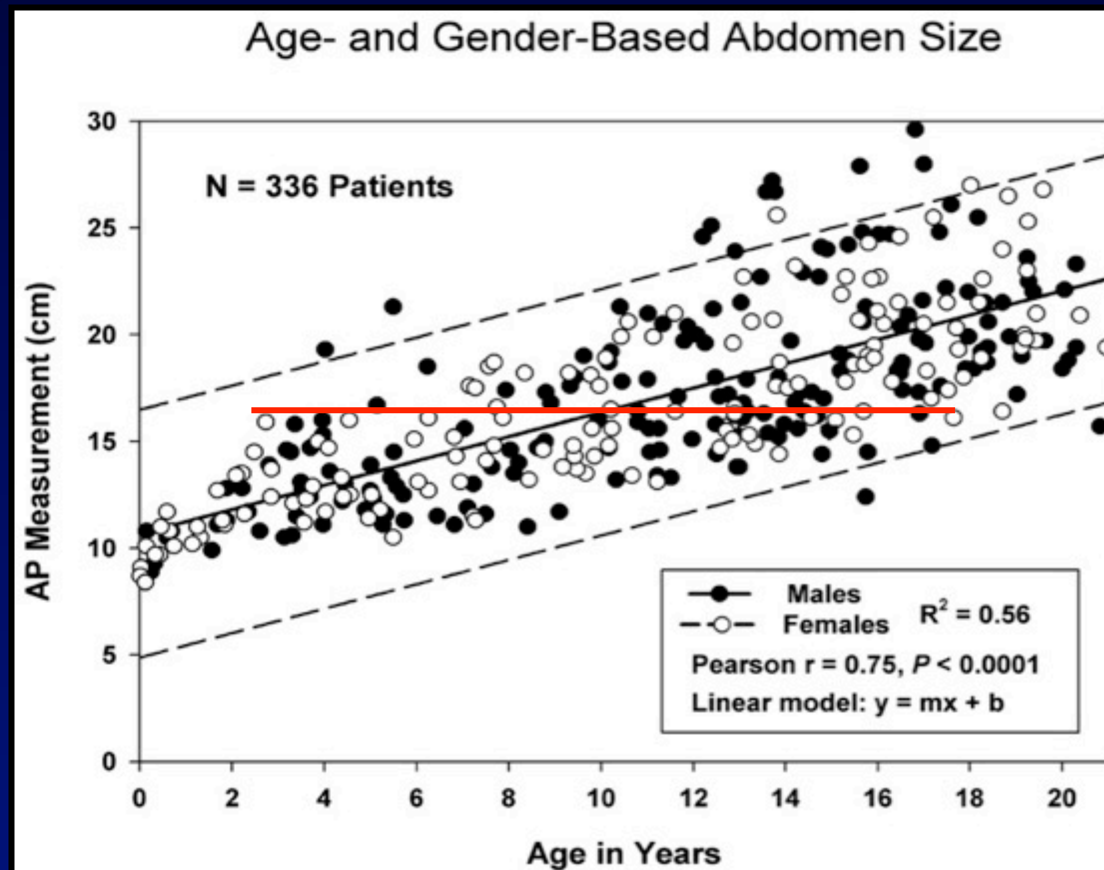




AGE vs PATIENT SIZE?

Same age patients vary dramatically in size.

- **Abdomens of:**
  Largest 3 year olds and
  Smallest adults are
  the same size.



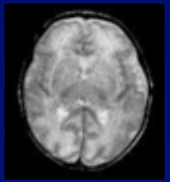
- **Patient cross sectional thickness, not age, should be used.**

PEDIATRIC IMAGING CHALLENGES

B. Patient Ages: Neonate to 21 year and Beyond

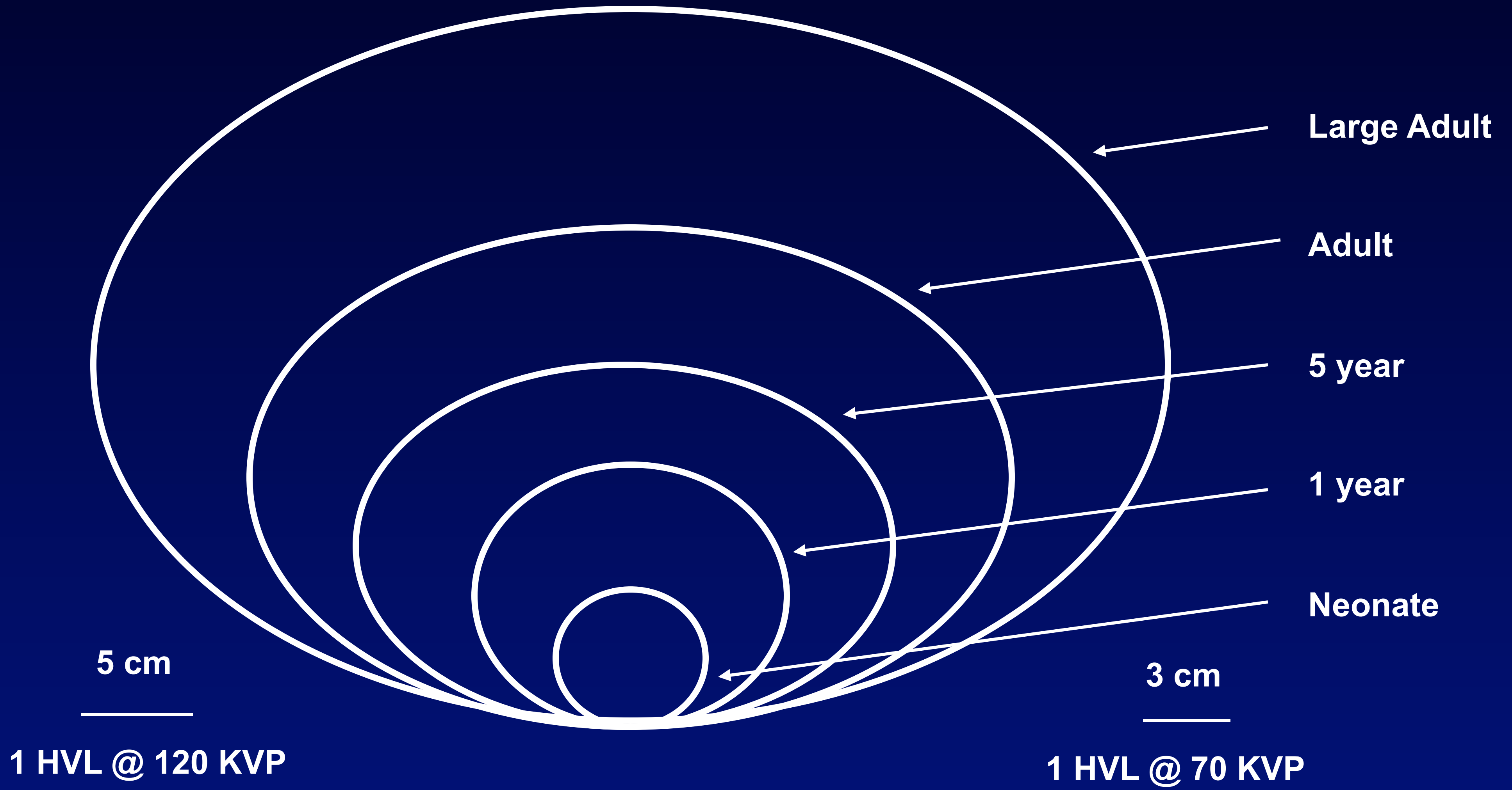
CT: 16 yr old: 335 lb

MRI: Neonate



PEDIATRIC IMAGING CHALLENGES

B. Patient Ages: Neonate to 21 year and Beyond



One Pediatric Advantage?

How can I get the necessary photon flux, radiation dose rate to the image receptor while reducing the radiation dose to the entrance plane of the pediatric patient?

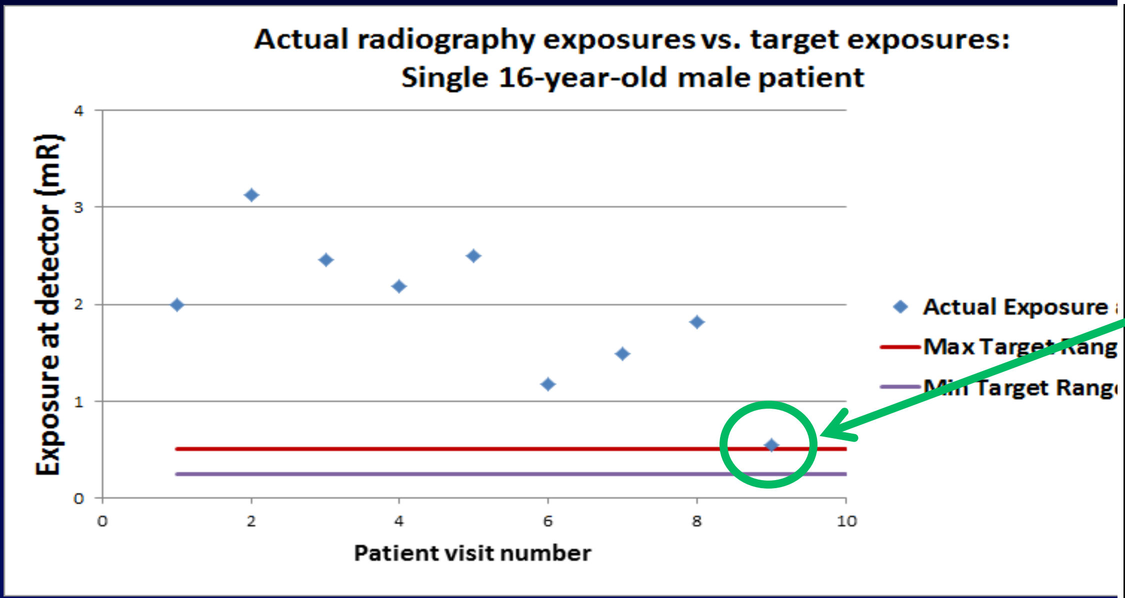
PEDIATRIC RADIOGRAPHIC TECHNIQUES

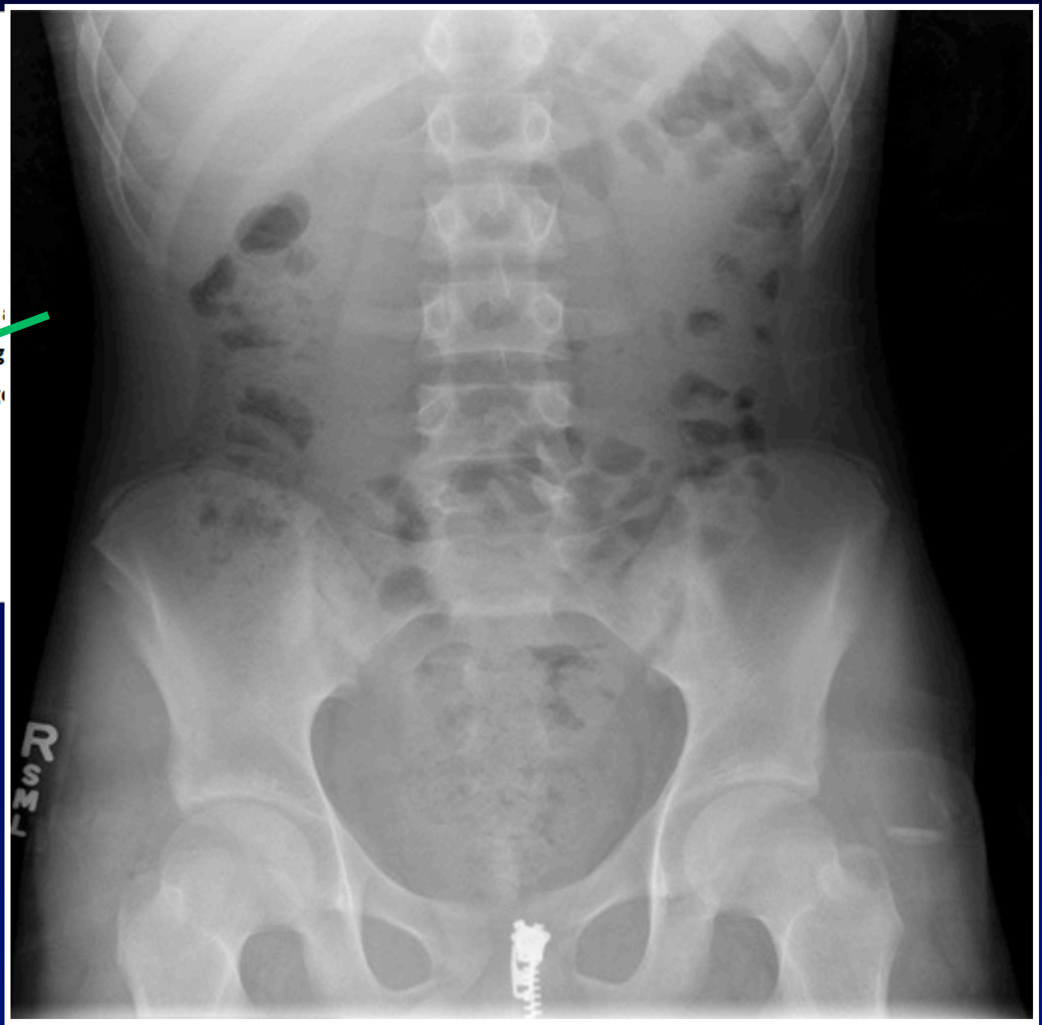
B. The Ugly

1. "We love CR. We can use <u>**ONE**</u> Radiographic Technique for <u>**ALL**</u> our Pediatric Exams."

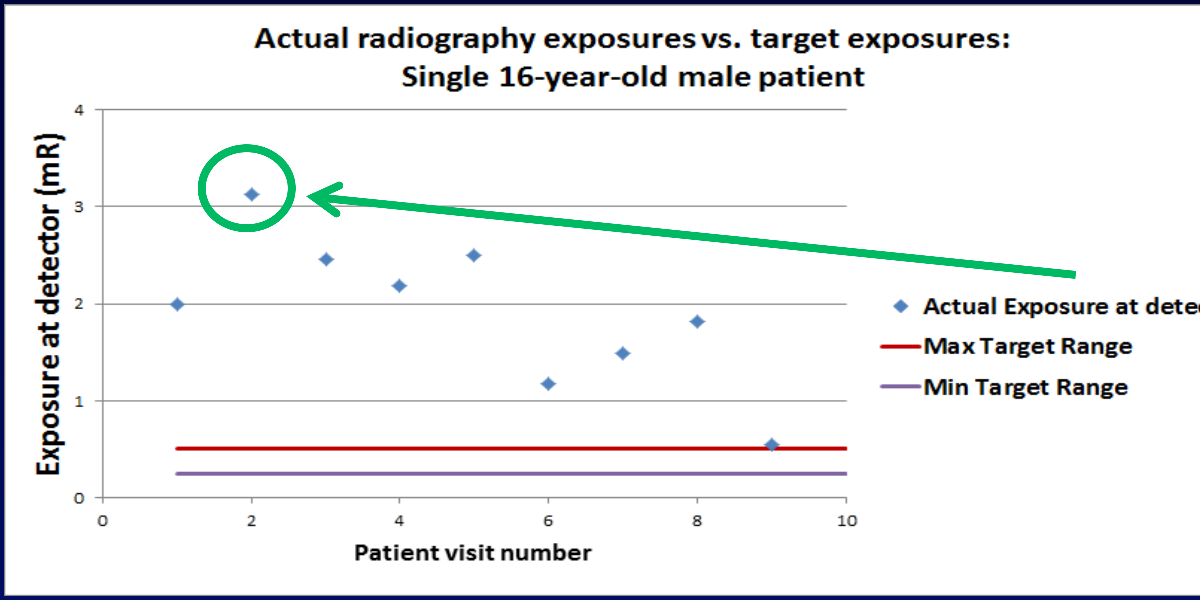
2. Dose Creep

One Patient's Experience





One Patient's Experience

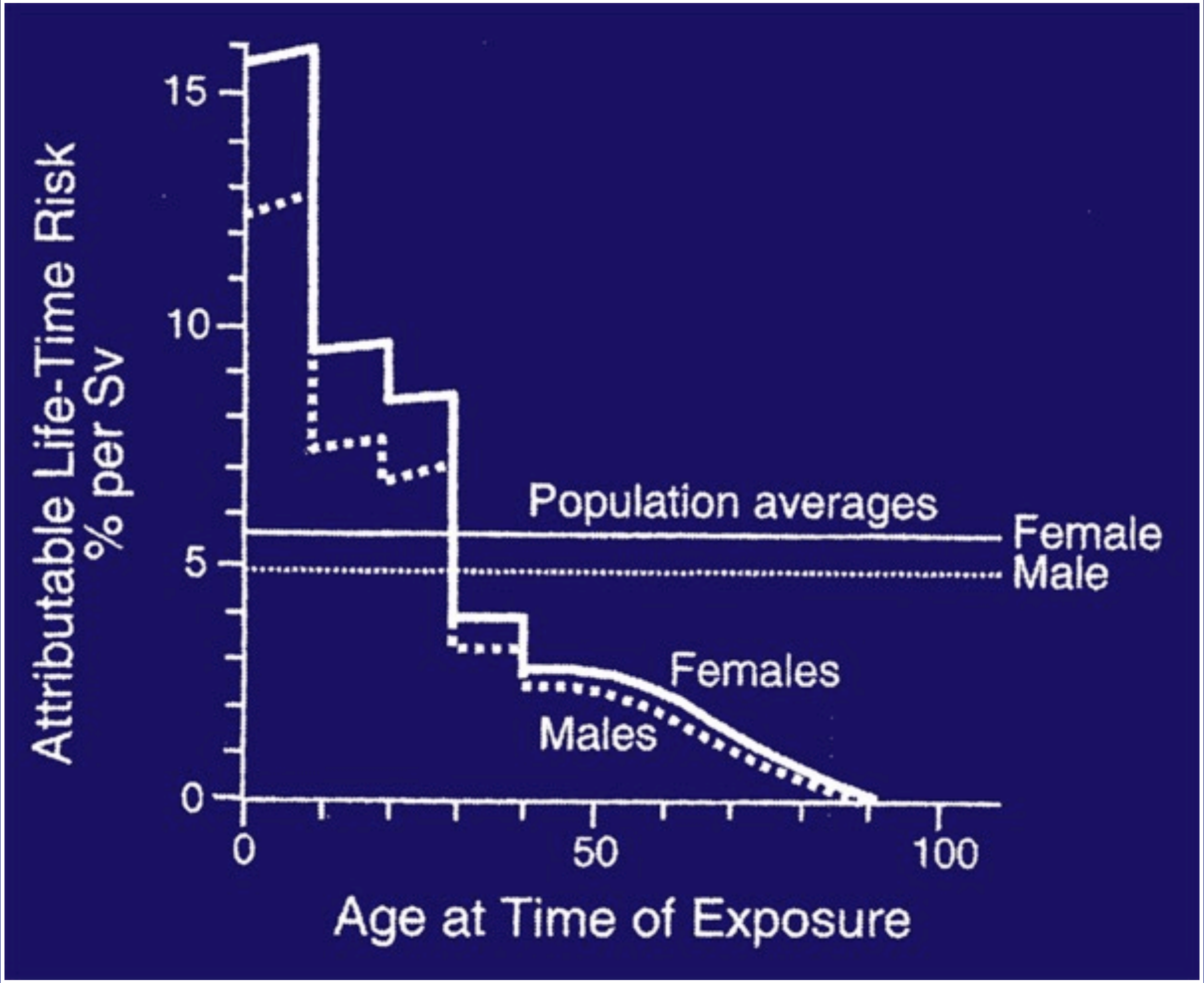


One Patient's Experience

Big Deal or Mountain Out of Mole Hill?

I. Radiation Induced Cancer Lifetime Risk From 1 Sv Dose

1. All Ages
   a. 6% Female
   b. 5% Male
2. First Decade
   15%
3. Middle Age
   1 - 2 %



Direct Radiography (DR) Dilemma

State-of-the-Practice of pediatric DR with respect to patient care[2] . . .

. . . leaves much to be desired!

Let's look at some of the reasons. Is the current problem:

- Responsibility of end user?
- Responsibility of manufacturers?

[2]Properly managed radiation dose and image quality as a function of patient size.

What Have We Learned from our DR Program?

Radiologists

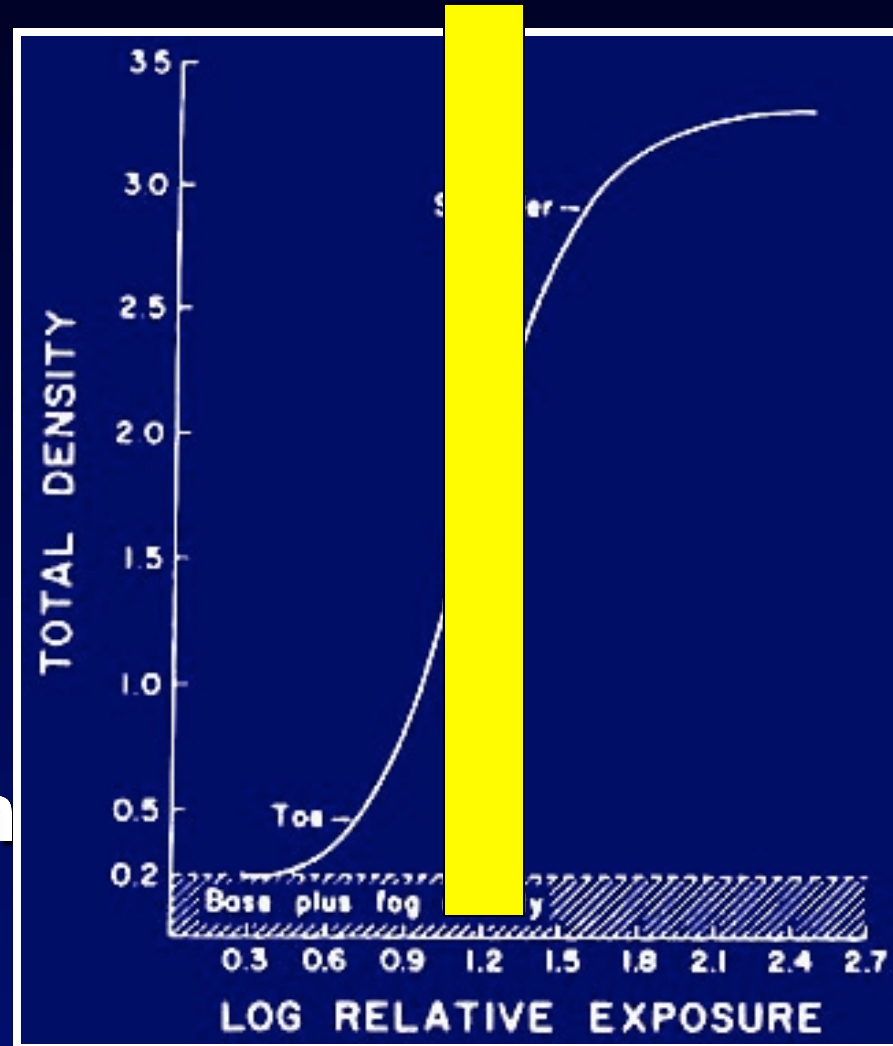
- Cannot provide meaningful feedback on image quality until all technologists are producing controlled radiographs!
- Must accept change in work patterns.
- Need to accept adequate to good as opposed to great image quality!

Film Characteristic Curve Shape

- **Automatic Quality Control**

  Radiographic technique Choices outside the narrow vertical band
  - Log rel exp = 0.3
  - Exposure range > 2

  at image receptor resulted in unacceptable radiograph
- **DR & CR eliminated that built in QC mechanism**



Detector Dose?

Why talk about **detector** dose as opposed to **patient** dose?

- Detector dose **relatively** constant despite patient size.
- Image quality driven by detector dose.
- Manufacturers provide an EI number.
  - EI number is dependent on image processing
    - Infamous ‘green’ snow

EI = 739

EI = 582

EI = 938

EI = 682

EI = 336

EI = 281

How Do We Fix This Problem?

- Technologist creates poor quality image
  - When technologist changes image processing, the EI Number changes
    - Is the image processing incorrect?
    - Is the detector dose incorrect?
      - Image acquisition is paramount
      - Radiologist's image qualtiy requirements.
    - Correct and carefully control detector dose
      - If image quality is substandard, the correction has to be image processing

Equipment Modifications for Pediatric CR/DR

Pediatric appropriate Anti Scatter Grids

- Removable
- Grid for 100 - 130 cm SID
- Grid for 180 cm SID
- One grid designed for 140 cm SID cannot do the job
  - Never work at 140 cm SID

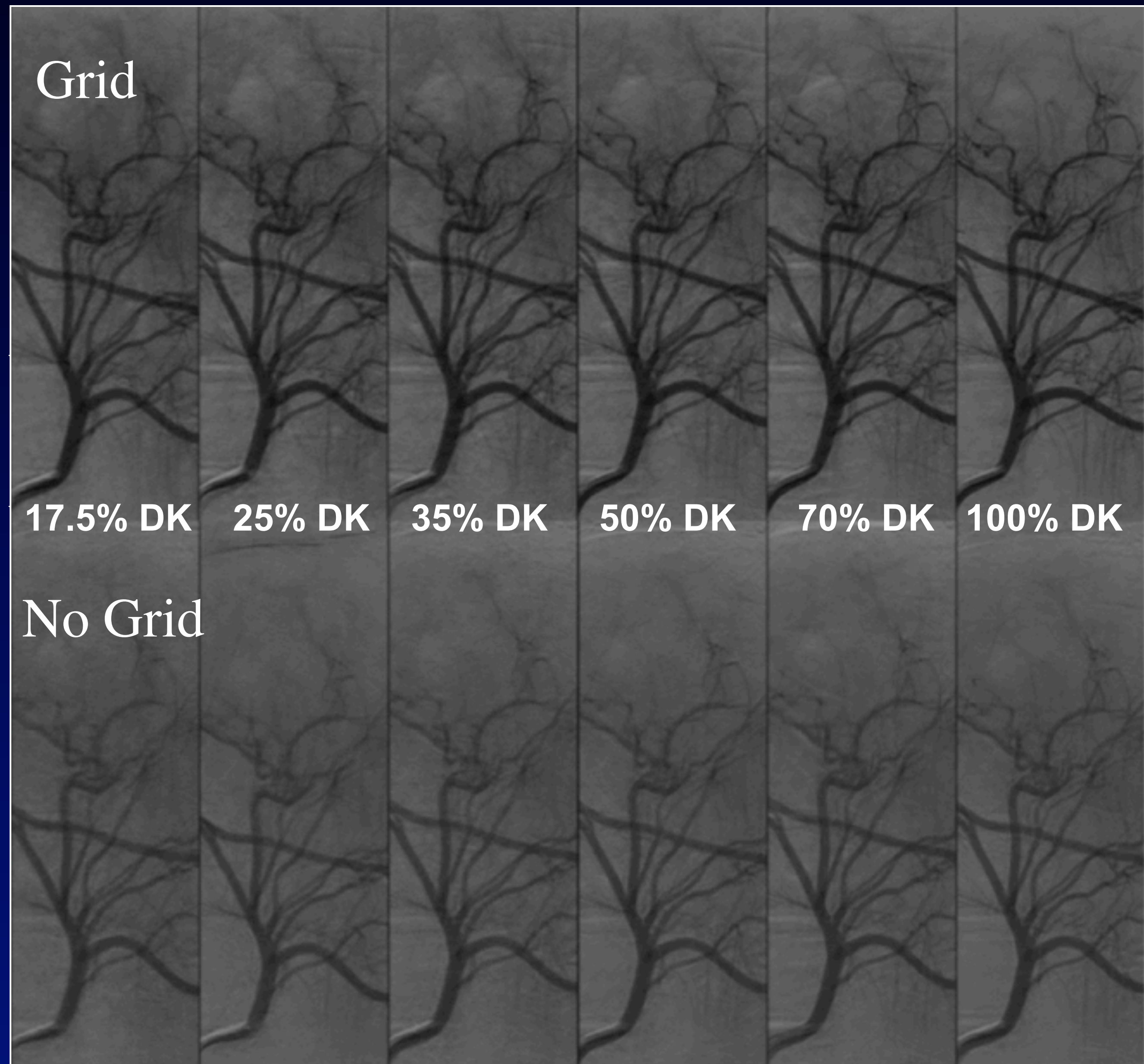
Equipment Modifications for Pediatric CR/DR

Anti-Scatter Grid In/Out: When?

- Pediatric patient dose reduction with small loss of image quality
- 10 cm thick body part
  - Cross sectional area also important
- New paradigm
  - Never remove the grid!

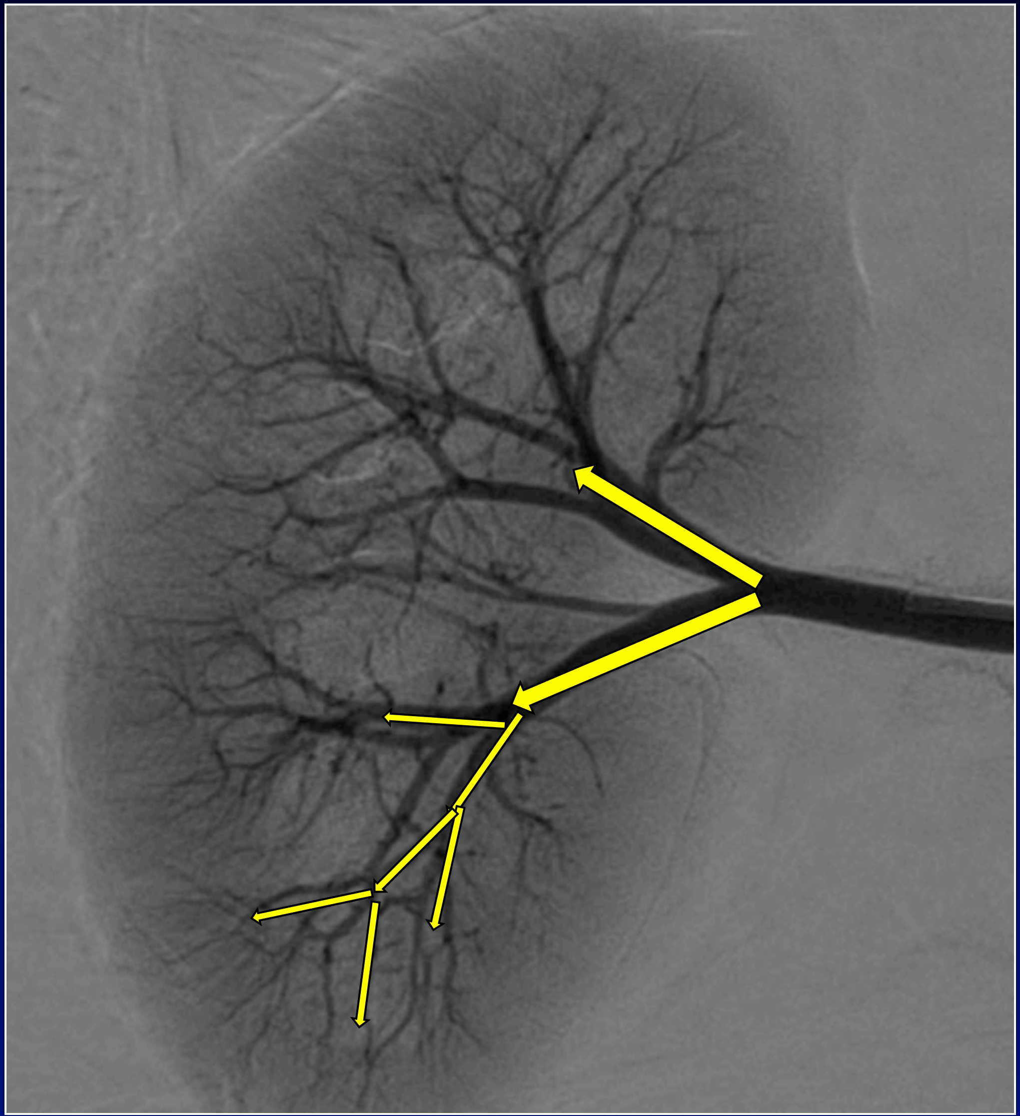
Anti Scatter Grid vs Detector Dose

- **Fixed Parameters**
  - 2 pulses/sec
  - 73 kV
  - 0.4 mm Cu
  - 1.25 mag factor
  - Collimation, FoV
- **Variables**
  - Detector Kerma (DK)
  - Piglet thickness
  - Grid placement



Anti Scatter Grid vs Detector Dose

Five pediatric radiologists evaluated 144 DSA runs twice each to assess effectiveness of anti-Scatter Grid (ASG)



0—non-diagnostic images
fail to depict arterial structures

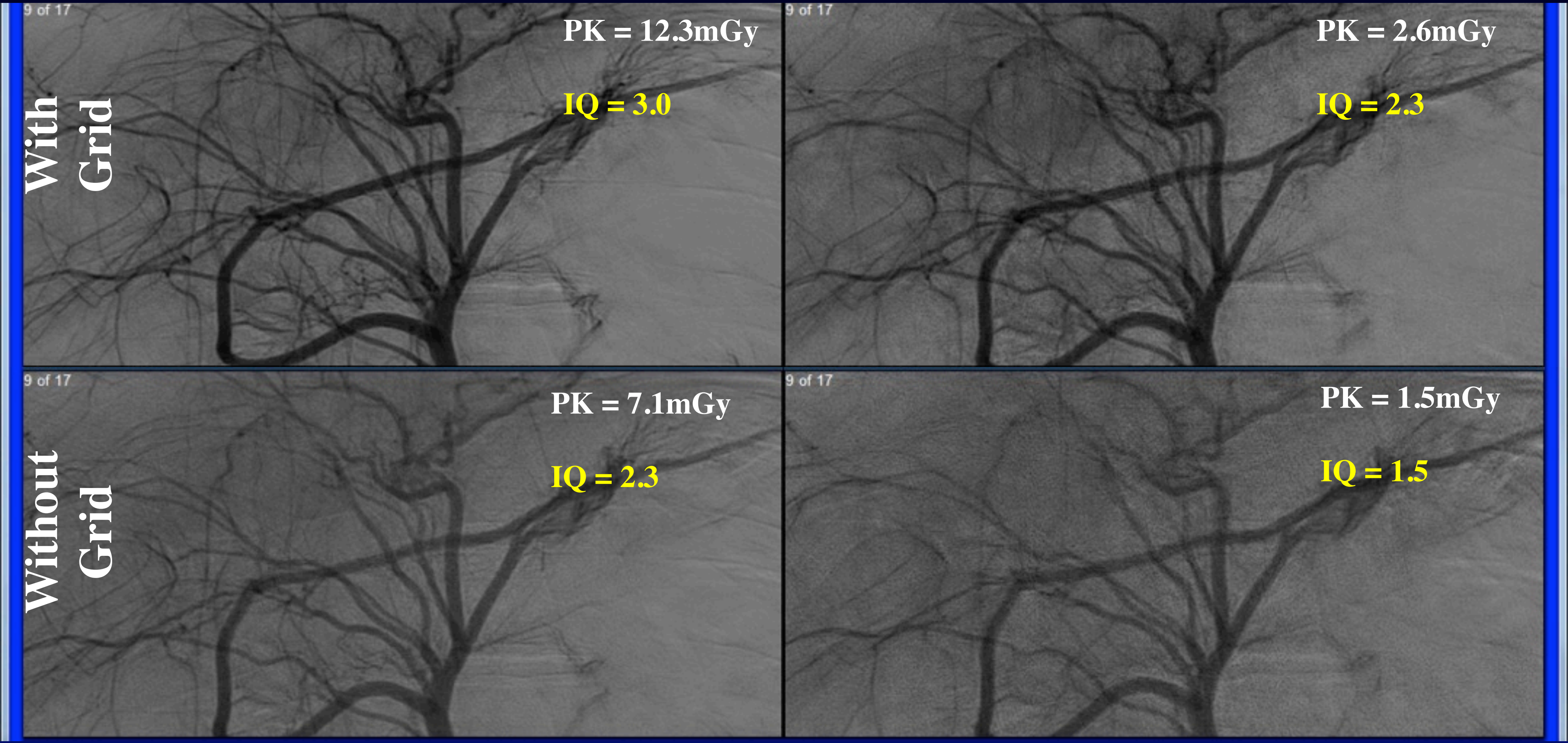
1—poor quality images
Diagnostic evaluation of <u>1st order</u> branches

2—intermediate quality images
Diagnostic evaluation of <u>2nd order</u> branches

3—high quality images
Diagnostic evaluation of <u>3rd order</u> branches

4—Excellent quality images
Diagnostic evaluation of <u>4th order</u> branches

ROC analysis investigated specific IQ requirements with or without Grid at minimum required vessel visibility of 2 or 3.

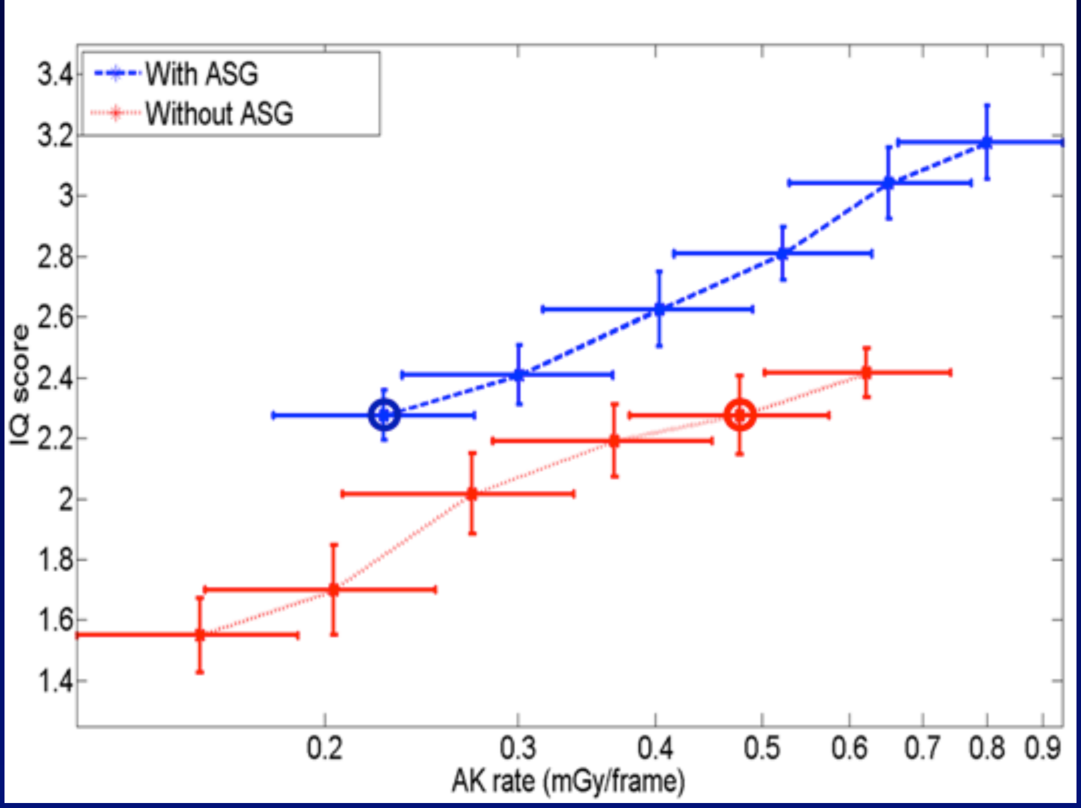


Hepatic Artery

Anti Scatter Grid vs Detector Dose

- Grid Removal: 26% Loss of dose AND Image Quality
  - Image Quality (IQ) vs patient air kerma with and without grid
  - IQ score of 2.3 with grid
    - EPX6 (17.5% DK)
    - 0.23 mGy
  - IQ score of 2.3 w/o grid
    - EPX2 (70% DK)
    - 0.48 mGy
  - PK w grid 50% of PK w/o Grid w same IQ score!

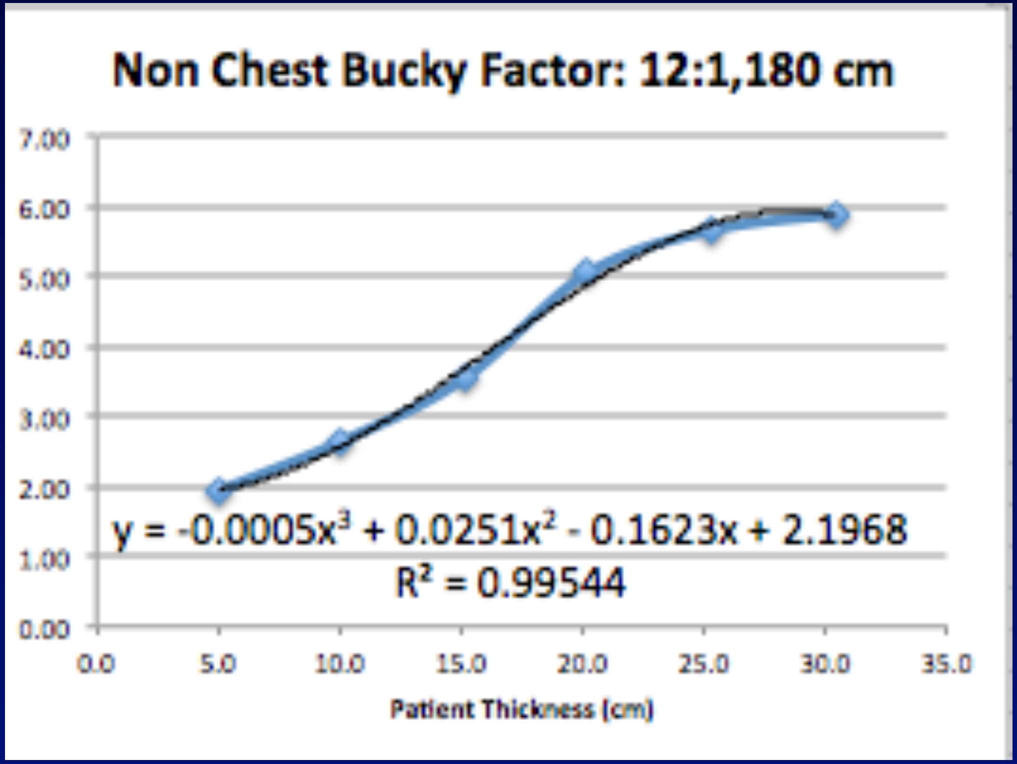
Strauss KJ, et al. JACMP 2015



Equipment Modifications for Pediatrics DR

Pediatric appropriate Anti Scatter Grids

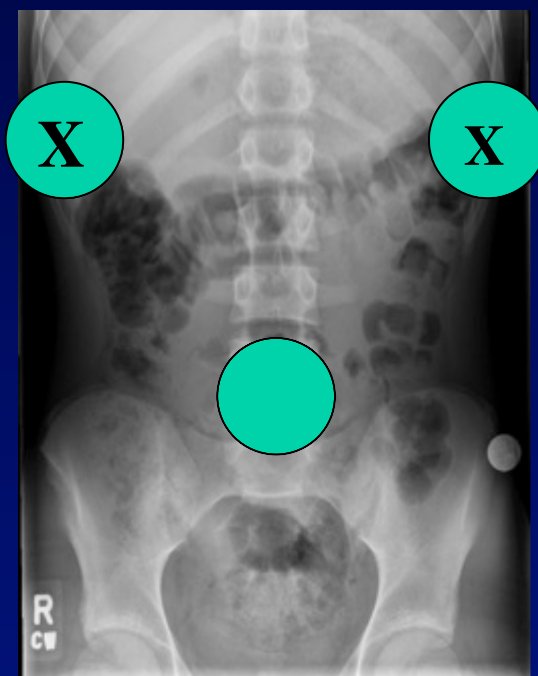
- **Bucky Factor:** increase in patient dose when a grid is used.
  - Ranges from 2 – 6
    - Patient size
    - Area of x-ray beam
  - Why is curve sigmoid In shape?



AEC Sensors

Pediatric appropriate AEC sensors:

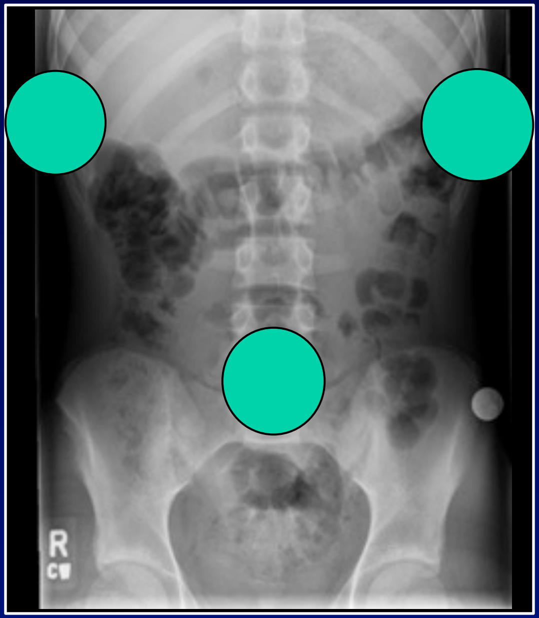
- 1 vs 3 Cell Detectors
- Designed for adults
- If cells 1 or 3 incorrectly covered by collimated x-ray field,
- One company automatically shuts off uncovered cell(s).
  - Great concept, but incorrectly designed and implemented!



AEC Sensors

Pediatric appropriate AEC sensors:

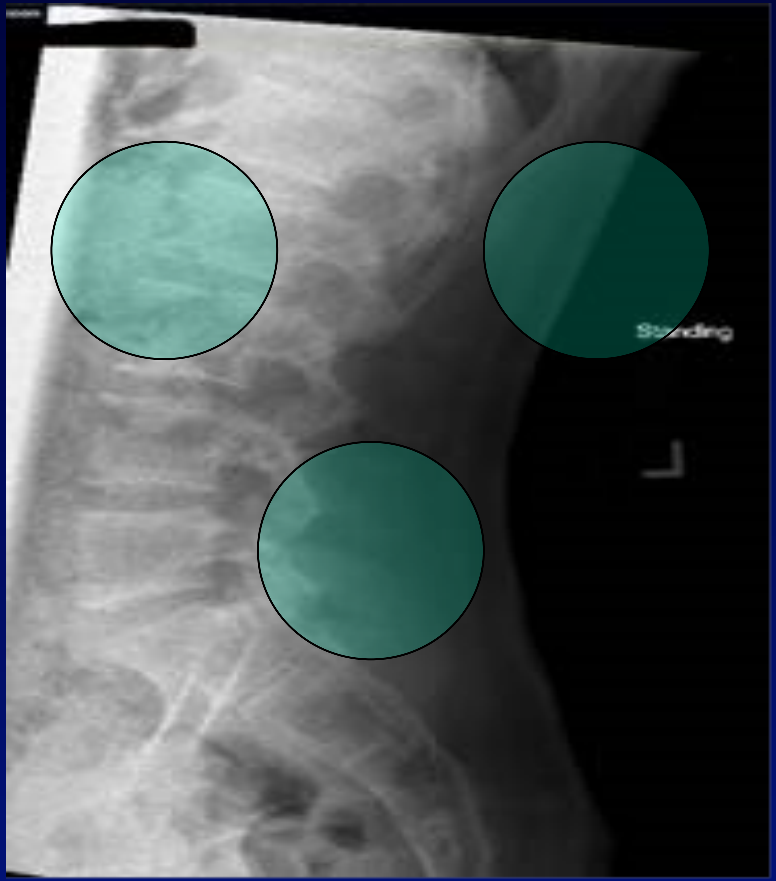
- 1 and 3 Cell Detectors are completely covered by x-rays
- 1 & 3 cells remain active
- 1 & 3 not completely covered by anatomy.
- Shutdown exposure prematurely.
  - Feature as it stands cannot be used!
  - This type of problem difficult to find without a dashboard!



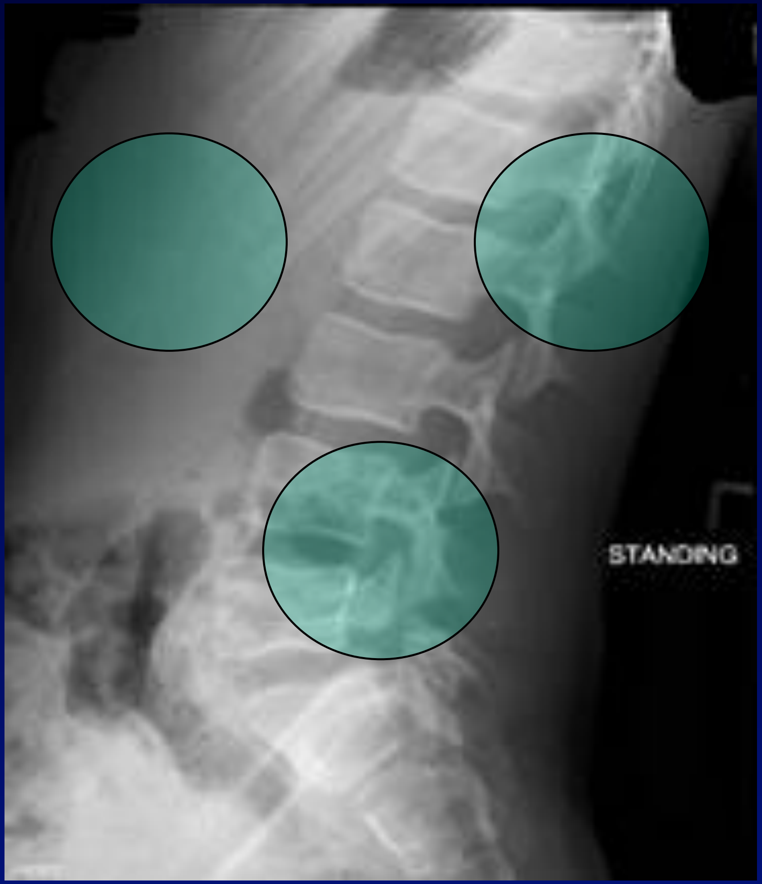
AEC Sensors

Centering the patient is crucial. The patient's spine must be over the center cell.

Poor centering. Underpenetrated.



Centered. Good image.



Equipment Modifications for Pediatric DR

Pediatric AEC Calibration:

- Set detector dose (type of study):
  - ~ 0.3 mrad ~ 2.5 μGy for adult trunk
  - ~ 1.2 mrad ~ 10 μGy for adult extremities
  - ~ Double above for child abuse studies and DMD patients
    - Why change for extremities, child abuse studies, DMD patients?

Equipment Modifications for Pediatric DR

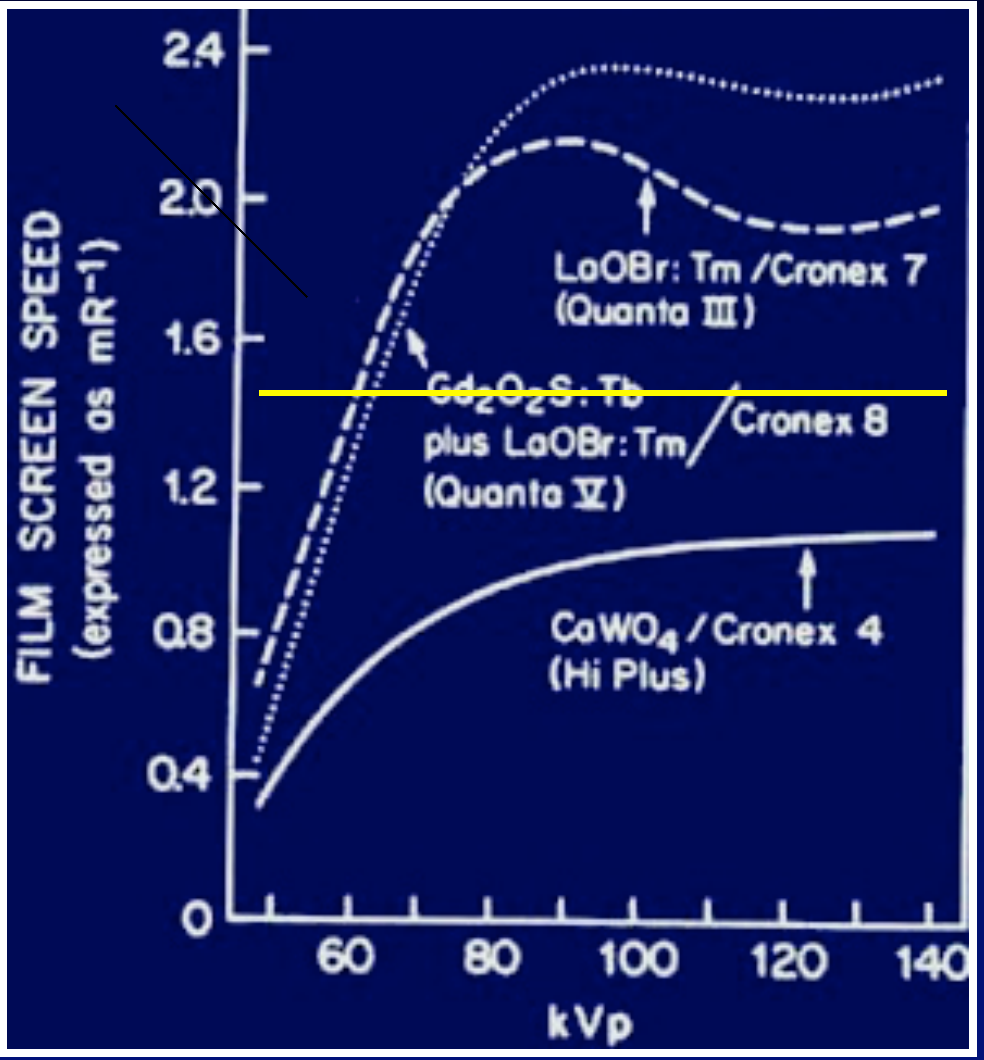
Pediatric appropriate Automatic Exposure Control (AEC) calibration:

- Set detector dose (patient size):
  - New Born Dose ~ 2 x adult dose
    - Why?
    - Experience of radiologists?

Equipment Modifications for Pediatric DR

What has not been addressed for DR AEC?

- Energy Response
- Film-Screen combinations did not have flat energy response similar to DR detectors.



Equipment Modifications for Pediatric DR

Pediatric appropriate X-Ray Beam Filtration

- Filters with z > 13 (Al) allow more radiation delivery at detector with less radiation dose to the patient's skin
  - Higher techniques required
  - Less contrast in image
    - Match Filter Thickness and kV
    - Maximize Figure of Merit = CNR^2 / Dose
  - Conventional understanding of appropriate technique factors obsolete

Equipment Modifications for Pediatric DR

Pediatric appropriate X-Ray Beam Filtration

- Filter and kV matched by FoM at given patient thicknesses
  - Select remaining technique factors: must select tube current and exposure time independently
    - Exposure time short enough to freeze motion
    - mAs needed for detector dose with kV/Filter by adjustment of tube current
    - Tube current dependent on focal spot size and required mAs

OPERATIONAL ISSUES

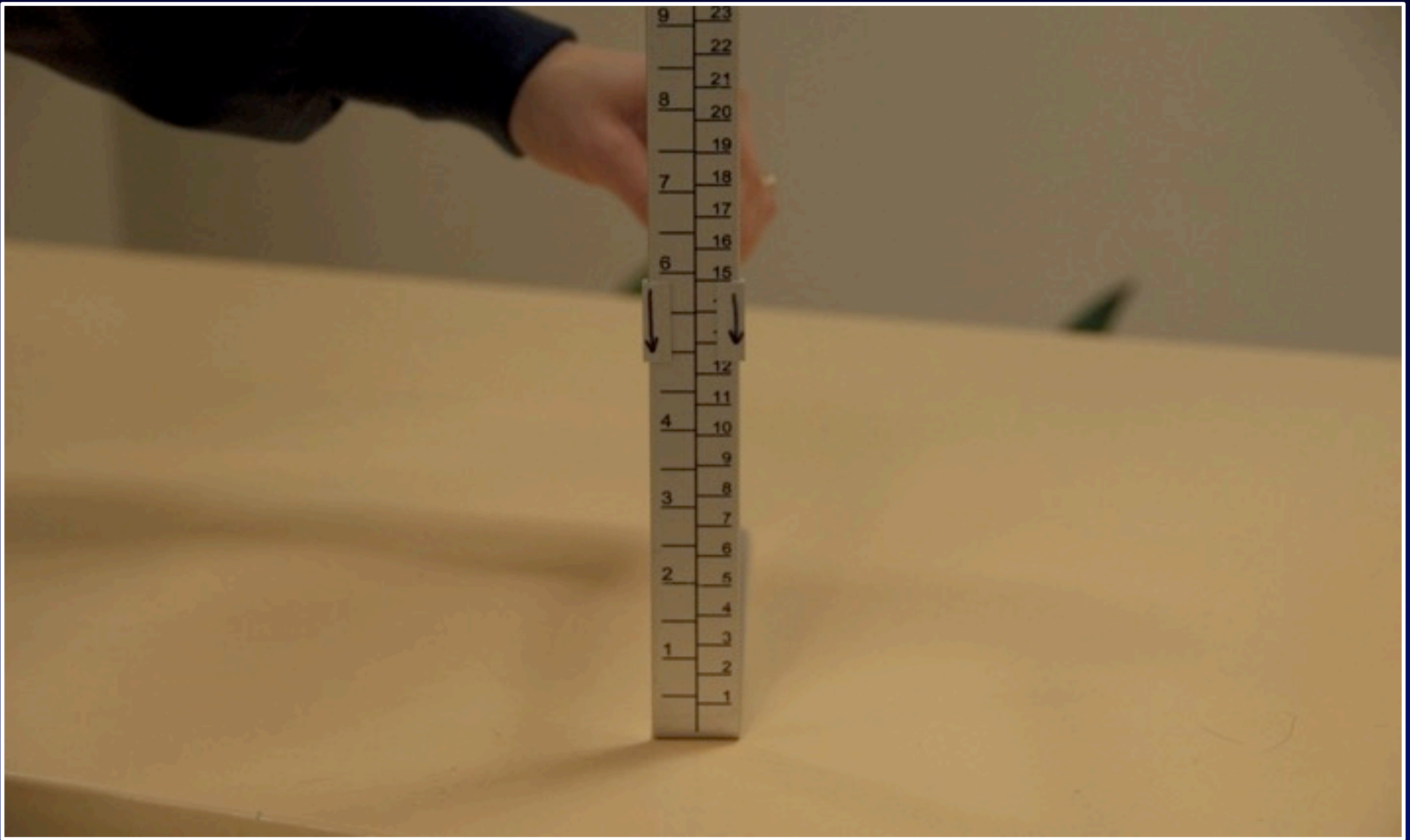
A. Comprehensive Training of Staff Fosters

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

CR/DR measuring

Calipers

- Centimeters are listed on the right side
- The arrows pointing down indicate where to read the measurement



Patient Size

Inaccurate Measurement

- Accurate thickness measurements are directly related to image quality and dose.
  - Techologist's measurement recorded as **4 cm**
  - PACS measurement shows it should have been recorded as **6 – 7 cm**

Correct

Incorrect

- **3 cm is a Half Value Layer of Tissue**

Eliminate Guesswork

- Programed parameters in generator console tied to patient thickness and exam type.
  - Measure Patient Thickness
  - Position patient
  - Select patient size and type of exam on console
  - Verify SID and use of grid

Eliminate Guesswork

- Programmed factors in generator console.
  - SID: 40, 48, 56, 72, and 102 inches
  - Grid use
  - X-ray Tube Voltage and Filter Thickness
    - Soft Tissues
    - Chest
  - Focal Spot Size: specified tube current
    - 5 msec $\leq$ Exposure time $\leq$ 15 msec
    - Patient size drives tube current
      - Manual vs AEC mode?

A Potential Useful Tool

Great idea for pediatrics

- No follow through by vendor!

TECHNIQUE CHART

	NEWBORN	BABY	CHILD	SMALL	NORMAL	LARGE	X-LARGE
EXTREMITIES	1 cm	2 cm	3 - 4 cm	5 – 7 cm	8-10 cm	11-13 cm	14-18 cm
TRUNK	5-8 cm	9-12cm	13-17cm	18-23cm	24-29cm	30-36cm	37-44cm

Sample Technique Chart

Abdomen

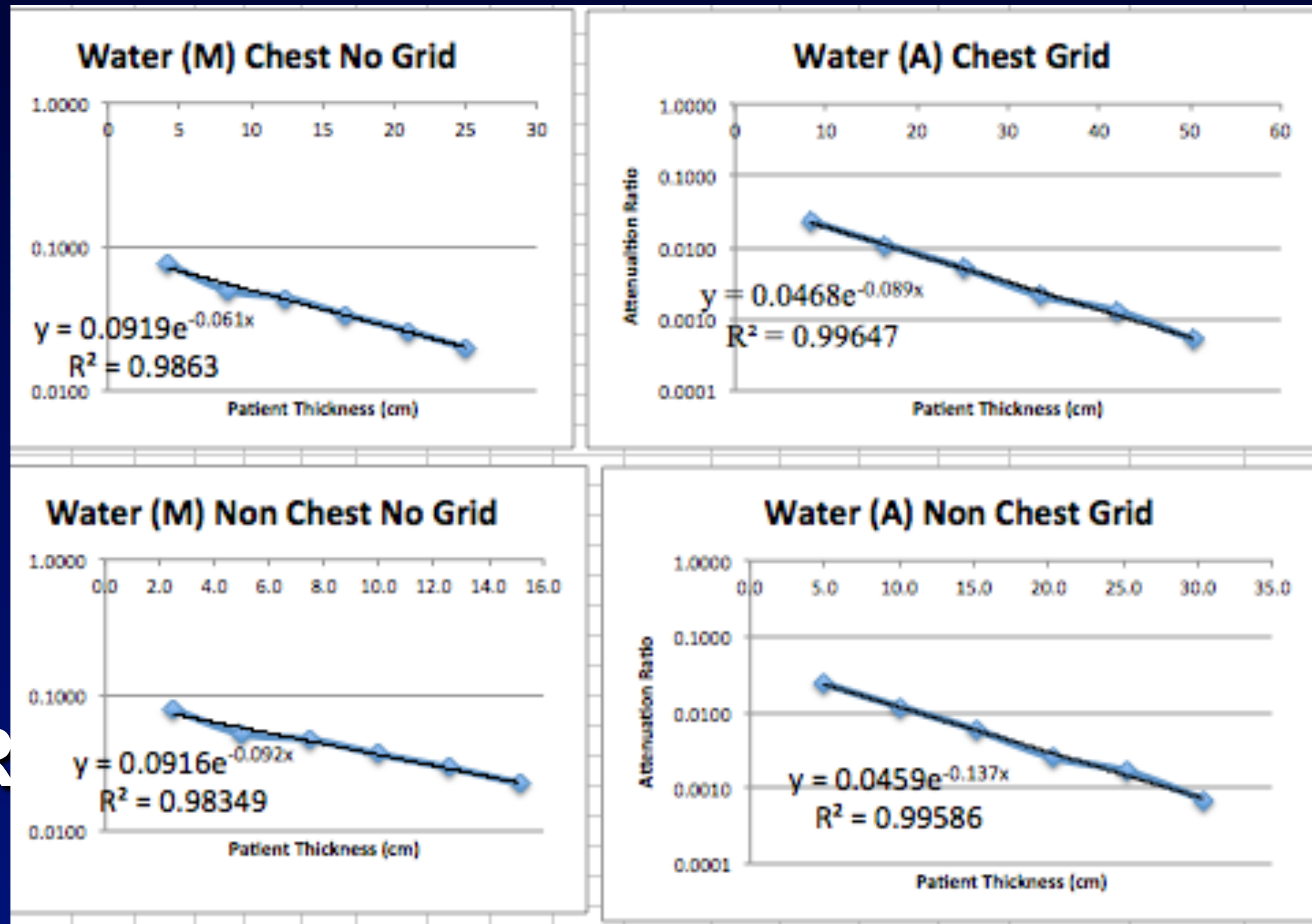
	Newborn	Baby	Child	Small	Normal	Large	X-Large
	5 - 8 cm	**9 - 12 cm**	**13 - 17 cm**	**18 - 23 cm**	**24 - 29 cm**	**30 - 36 cm**	**37 - 44 cm**
KV	64	77	79	83	85	89	95
mA	200	250	500	800	630	630	630
msec	10	12.5	12.5	16	40	80	160
mAs	2	3.1	6.3	12.8	25.2	50.4	100.8
FOCAL SPOT	S	S	L	L	L	L	L
AEC	OFF	OFF	AEC	AEC	AEC	AEC	AEC
SPEED	NA	NA	S400	S400	S400	S400	S400
DENSITY	0	0	1.5	1	0	-1	-1
FILTER	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.1**	**0**
GRID	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
DOSE (μGy)	**2x**	**1.8x**	**1.5x**	**1.4x**	**1.1x**	**1.1x**	**x**
CELLS	**NA**	**NA**	**2**	**2**	**2**	**2**	**2**

ATTENUATION MODELING

Reasonable Fits: $R^2 \sim 1$

μ values differ w & w/o grid; chest vs soft tissue

- Can estimate detector air Kerma if x-ray tube output is known with Exposure factors from RDSR



Initial Feedback

- I went to school to be able to do this!
- I'm not a button pusher.
- This is going to slow us down.
- This dumbs down the process!

Feedback Today

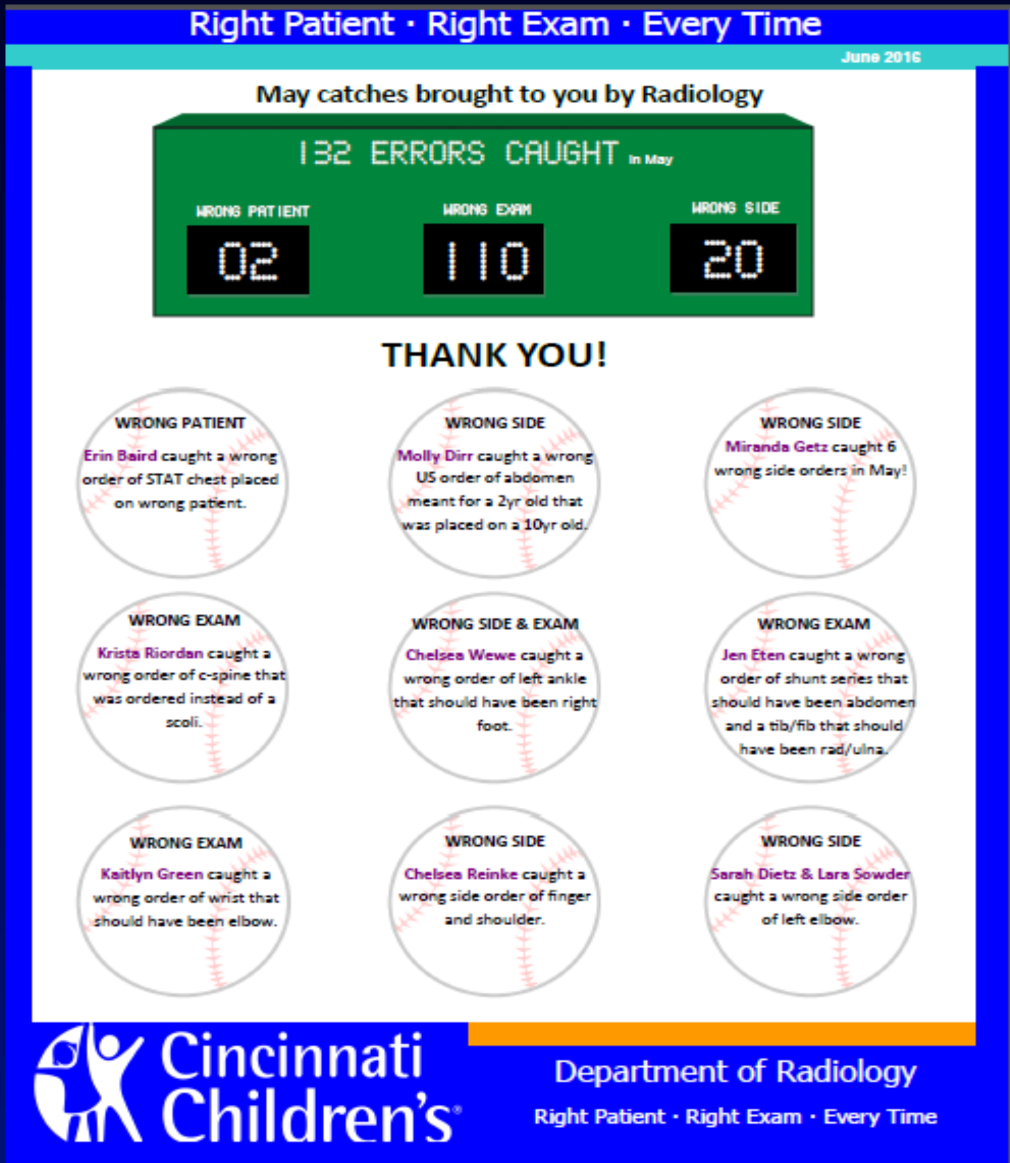
- Our measuring program speaks volumes about our personalized care for our patients.

- It's not a guessing game anymore. We have tools at our fingertips today that we didn't have in the past.

- As a tech who used to set her own kV, mA, time and overexposed people, consistency in imaging is nice.

Radiology Quality Improvement Team

Great Catches


Right Patient · Right Exam · Every Time

June 2016

May catches brought to you by Radiology

132 ERRORS CAUGHT in May

WRONG PATIENT	WRONG EXAM	WRONG SIDE
02	110	20

THANK YOU!

WRONG PATIENT
Erin Baird caught a wrong order of STAT chest placed on wrong patient.

WRONG SIDE
Molly Dirr caught a wrong US order of abdomen meant for a 2yr old that was placed on a 10yr old.

WRONG SIDE
Miranda Getz caught 6 wrong side orders in May!

WRONG EXAM
Krista Riordan caught a wrong order of c-spine that was ordered instead of a scoli.

WRONG SIDE & EXAM
Chelsea Wewe caught a wrong order of left ankle that should have been right foot.

WRONG EXAM
Jen Eten caught a wrong order of shunt series that should have been abdomen and a tib/fib that should have been rad/ulna.

WRONG EXAM
Kaitlyn Green caught a wrong order of wrist that should have been elbow.

WRONG SIDE
Chelsea Reinke caught a wrong side order of finger and shoulder.

WRONG SIDE
Sarah Dietz & Lara Sowder caught a wrong side order of left elbow.

Cincinnati Children's

Department of Radiology

Right Patient · Right Exam · Every Time


Right Patient · Right Exam · Every Time

March 2016

FEBRUARY SCORES

126 ERRORS CAUGHT

WRONG PATIENT	WRONG EXAM	WRONG SIDE
02	98	26

Great catches!

WRONG PATIENT
Kristina Stenger caught a wrong US patient order after family questioned the order and she called ordering Dr. to verify.

WRONG PATIENT
Megan Little caught a wrong patient chest xray order on a 5 month old patient.

WRONG SIDE
Molly Dirr caught a wrong side order of US extremity.

WRONG EXAM
Becky Barth & Kathy Lonzo caught a wrong MRI order of face/orbits/neck that should have been arm.

WRONG EXAM
Kristi Baker caught a wrong order of foot that should have been knee.

WRONG EXAM
Kayla Jones caught a wrong order of lower extremity that should have been chest.

WRONG EXAM
Miranda Getz caught a wrong exam of tib/fib that should have been forearm.

GREAT CATCH
Krystal Klayer caught a wrong order of bilateral hips that should have been right femur.

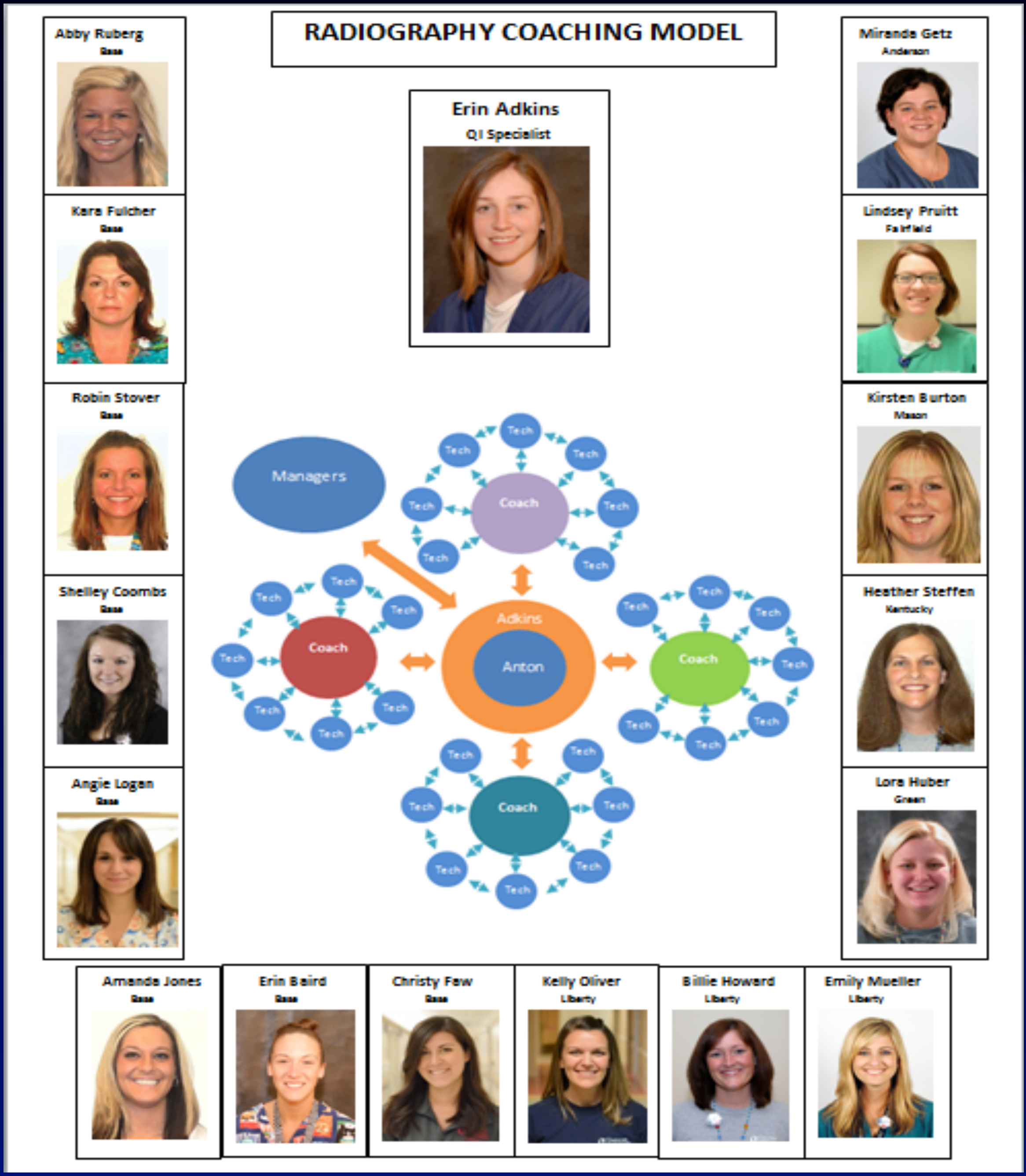
WRONG SIDE
Robin Stover, caught a wrong side finger order on a 8 yr old patient.

Cincinnati Children's

Department of Radiology

Right Patient · Right Exam · Every Time

- 16 Coaches
- 80 technologists are divided up and assigned to a coach's list for updates



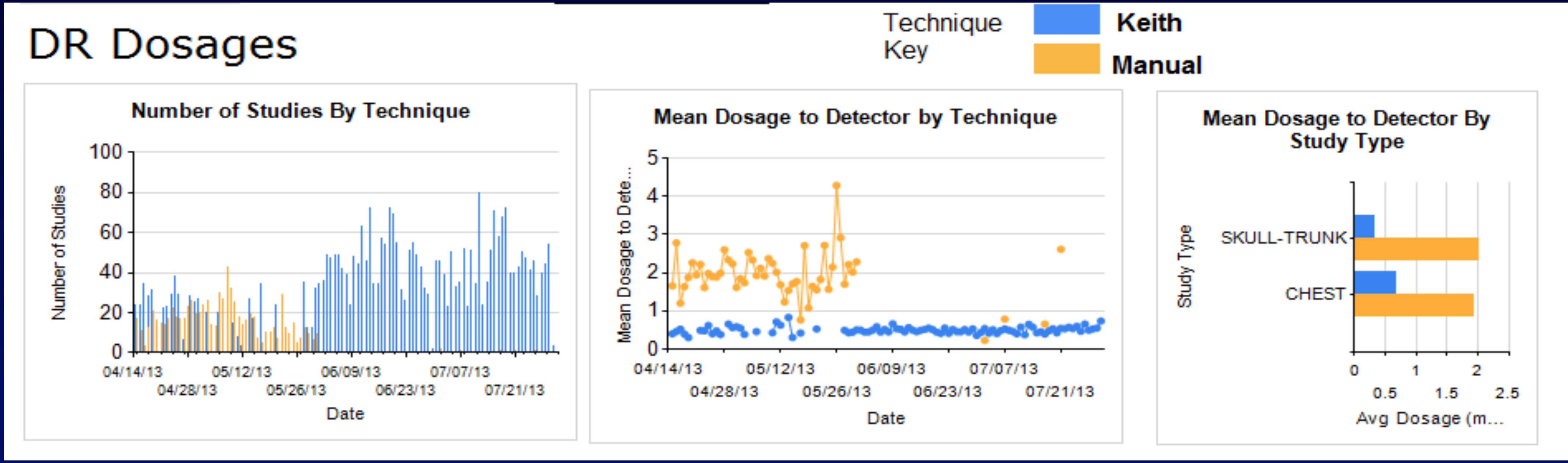
Must Monitor Performance of Program Continually

Image receptor air Kerma for each exposure

Patient air Kerma

Computer Dashboard Necessary

Here is a look at what you have achieved



Outstanding compliance

Less variability

Lower doses

What Have We Learned from our DR Program?

- Must overcome as many of the vendor's deficiencies as possible.
  - Leverage design strengths of vendor's equipment
  - Minimize equipment's design deficiencies

What Have We Learned from our DR Program?

- **Must overcome as many of the vendor's deficiencies as possible.**
  - Quality of control room monitor
  - Calibration of control room monitor
  - AEC Sensor Size and Configuration

Final Thought . . .

Children are not just small adults . . .

BUT

. . . most adults are big babies!!

Conclusions

- A comprehensive DR QA Program is not trivial
- Analyze your resources and your availability and
  - DO SOMETHING to improve pediatric DR
- Pick the low hanging fruit
  - Easier equipment modifications
  - Standardize everyone on some level of program
    - Size based technique charts
    - Measure size of pediatric patients
- Largest opportunity for dose savings is standardization of operations, not detector efficiencies or the use of spectral filtration.


I'D LIKE TO DO SOME-THING REALLY SIGNIFICANT WITH MY LIFE .... MAYBE BECOME A GREAT WORLD LEADER AND SAVE THE EARTH FROM NUCLEAR DEVASTATION, FEED ALL THE HUNGRY, OR MAYBE EVEN TRAVEL TO FAR AWAY PLANETS ....BUT WHO AM I KIDDING? I'M JUST A TINY BLACK FLY SITTING ON SOME BALD GUY'S HEAD.