Digital radiography (DR) ~~post processing techniques~~ for pediatric radiology

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Purpose

- Review common issues and solutions facing pediatric digital radiography (DR)
  - Exposure techniques
  - Post processing

- Review physics of DR post processing

Default technique set up

- A properly acquired DR image starts with proper technologist training/ongoing education

- Post processing should never replace proper technique
  - Patient alignment (*may be difficult in pediatrics*)
    - Center the patient (especially when using AEC)
    - Under 4 years old AEC not effective
  - Collimation
    - Techs will widen collimation for squirmy/noncompliant children
    - Poor collimation leads to
      - More scatter and less subject contrast
      - More direct detector exposure
   » May throw off post processing algorithms

Default technique set up

- Technologist should review technique before acquiring image
  - kVp, mAs
  - No grid under 1 yr old (extremities, and small parts in general)
  - Filtration
  - Adjust for patient size
  - Correct anatomical protocol is selected
    - e.g., skeletal survey
    - Techs will move the detector with out changing the protocol

- Technologists should review captured image
  - For adequate quality
  - EI/DI values

- Physicist/technologist QA
  - Review image data for outlier examination
   - Identify examination techniques/post processing problems

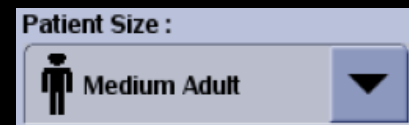# Default technique set up

- Review results in a measurable way
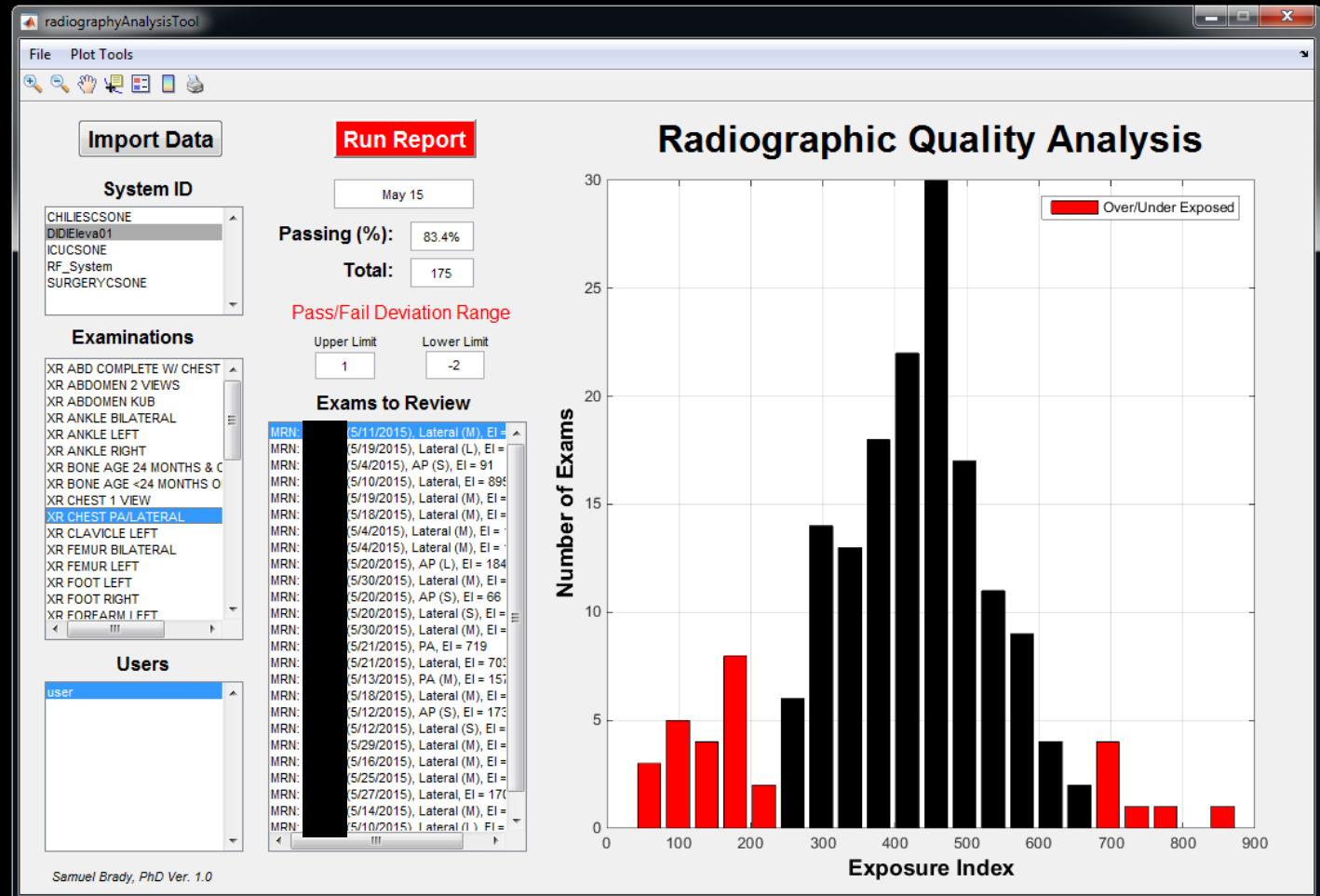
Default technique set up

- *Age/size*- adjusted protocols
  - RIS system interaction
    - Auto select technique factors based on body habitus (e.g., age)

  - e.g., Philips uses patient age
    - Based on bone density
      - (S) 0-12 mon
      - (M) 12-48 mon
      - (L) 48-96 mon
      - Adult equivalent > 96 mon

  - Post processing applied to the image
    - Manual vs. automatic
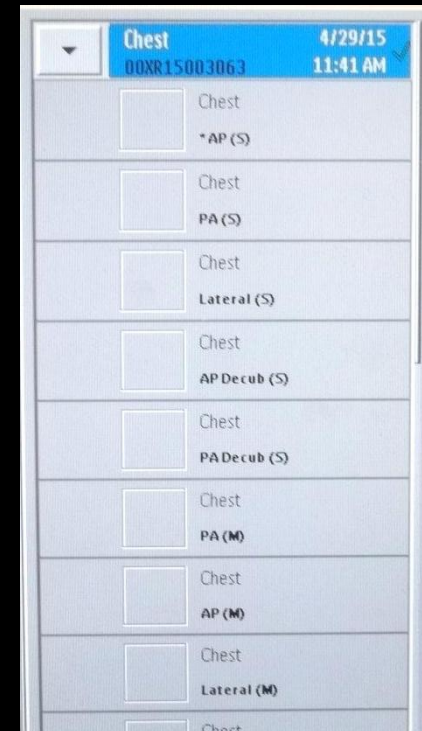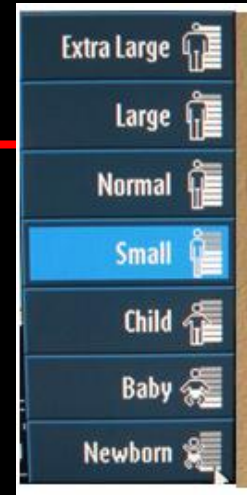
Default technique set up

- Review default age/size-adjusted technique factors
  - May not be defined for peds if you are an adult-centric site
  - kVp, mAs, grid options, etc.
  - Work with your vendor's apps specialists
  - AAPM TG 252/ACR
   - Methodology to set up ped technique charts

Patient Size : Medium Adult

	Newborn	Baby	Child	Small	Normal	Large
kV	40	40	40	42	45	47
mAs	2.2	2.4	2.7	2.0	2.0	2.0
mA	143.3	96.0	110.0	126.7	110.0	197.5
ms	30.0	50.0	50.0	30.0	30.0	40.0
Focal spotsize	small	small	small	small	small	small
AEC-mode	off	off	off	off	off	off
X-Ray regulation curve	1	1	1	1	1	1
Receptor sensitivity	S 400	S 400	S 400	S 400	S 400	S 400
Density corr. [exp.pts.]	0.0	0.0	0.0	0.0	0.0	0.0
Spectral filter	no filter	no filter	no filter	no filter	no filter	no filter
Grid position (Scopo)	centered	centered	centered	centered	centered	centered
Supported Grid	don't use grid	don't use grid	don't use grid	don't use grid	don't use grid	don't use
t Backup [ms]	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Q Backup mAs corr. [%]	1000	1000	1000	1000	1000	1000

ABDOMEN / ABD_1_VIEW / ABDOMEN_AP Standard Acquisition

			kV	mA	mAs (Fixed Only)	msec (B = Back-up Time)	Speed	Sid	Ion Chamber	Focal Spot
Small Adult		Fixed	75	400	6.4	16.0	400	100	N/A	Large	no
Med Adult		Fixed	80	500	12.5	25.0	400	100	N/A	Large	no
Large Adult		Fixed	85	640	20	31.25	400	100	N/A	Large	no
Small Ped		Fixed	65	200	2	10.0	800	100	N/A	Small	no
Med Ped		Fixed	65	250	3.2	12.8	640	100	N/A	Small	no
Large Ped		Fixed	70	250	6.4	25.6	500	100	N/A	Small	no
Small											

Philips

GE

Default technique set up

- Review default age/size post processing
  - Left image (adult protocol-general NA chest)
  - Right image [(S), (M), (L)-NAP chest]


Adult
D1 = 1.5
D2 = 2.0
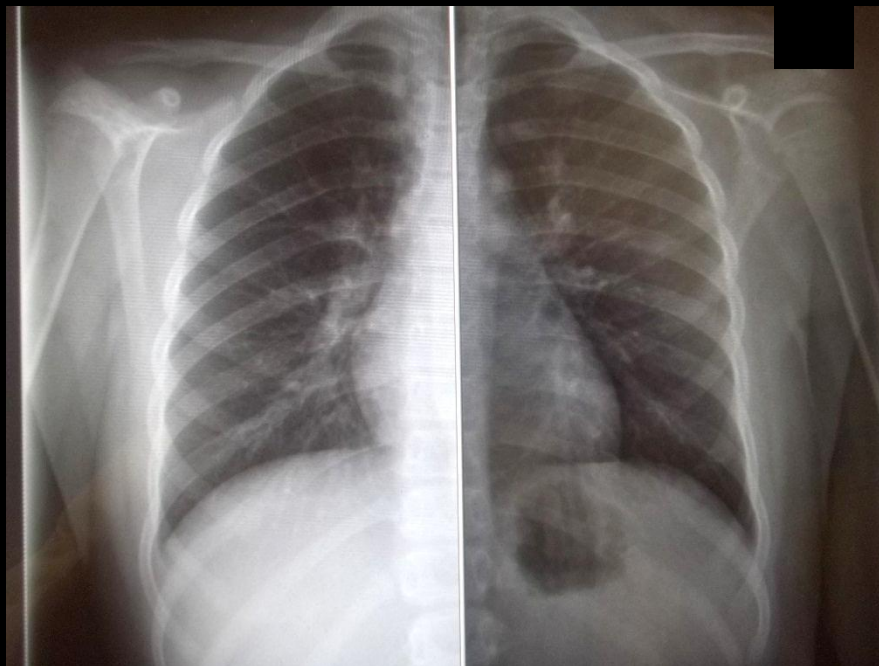
Pediatric
D1 = 1.8
D2 = 2.1

Density (D); D1 = VOI (lung field); D2 = soft tissue

Image post processing

- The image is created by taking the raw image through a series of steps before it is ready "for presentation"

  1. Image correction

     - Raw data

  2. For processing

     - Log compression

  3. Histogram formation/ comparison

  4. Segmentation

     - Detector exposure determination (K_{IND})

  5. Image processing

  6. For presentation
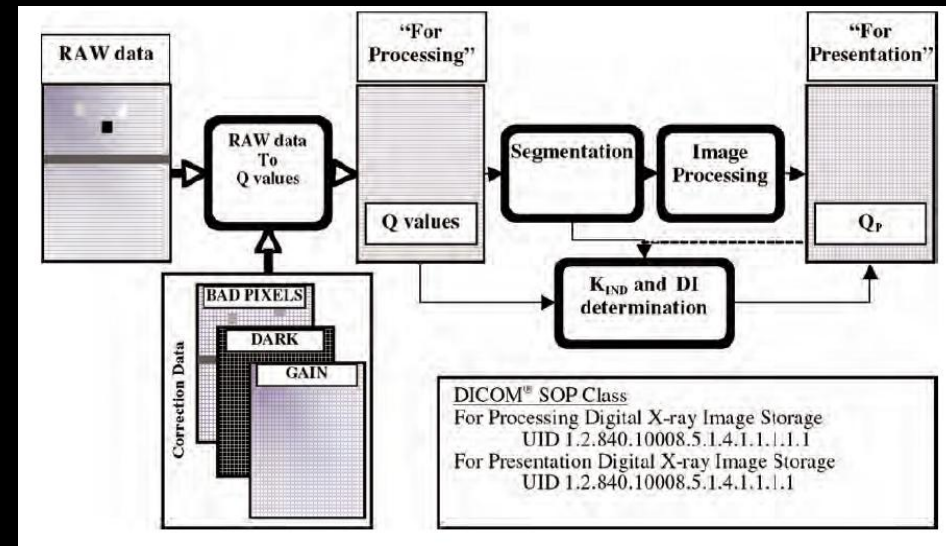
AAPM Report 116, Figure 2

Caveat

- Calibrate DR viewing monitor if possible
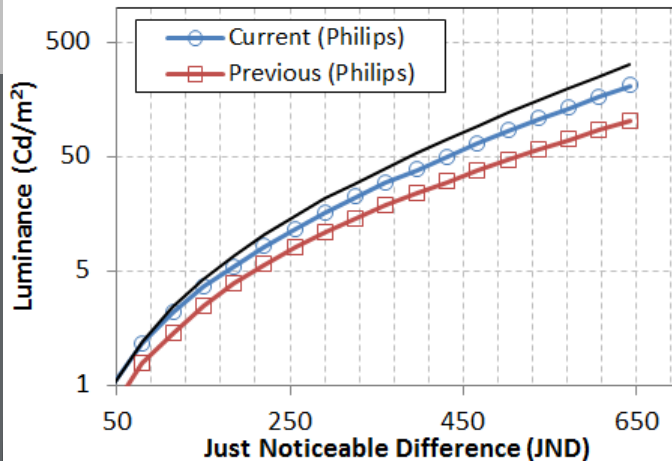- If not possible, verify processed images on a diagnostic quality monitor

Image post processing

- **First**, the image is corrected from its raw state
    - Dark noise correction(I_d)
    - Gain correction (I_g)
    - Correct digital detector imperfections in Del (DEXEL)
- **Second**, the image undergoes a log transformation and normalization
    - Pixels in "for-processing" image are referred to as "Q"-values (AAPM TG 116)
    - $Q_K = 1000 * log_{10}\left[\dfrac{K_{STD}}{K_0}\right]$
    - Q_K: is calculated to relate Q to a known "standardized" radiation exposure (K_{STD})
        - *e.g.*, Philips' 400 sensitivity/speed ~ 2.5 µGy detector entrance dose
    - $K_0 = 0.001$ µGy; $K_{STD} \geq K_0$

Image post processing

- Pixel values within for-processing image are organized into a histogram
  - Histogram x-axis represents exposure amount
  - Histogram y-axis displays number of pixels for each
    exposure
  - Low kVp = wide histogram
  - High kVp = narrow histogram
  - Underexposed histogram is skewed left
  - Overexposed histogram is skewed right
  - Shape of the histogram stays fairly
    constant for each exposed body part
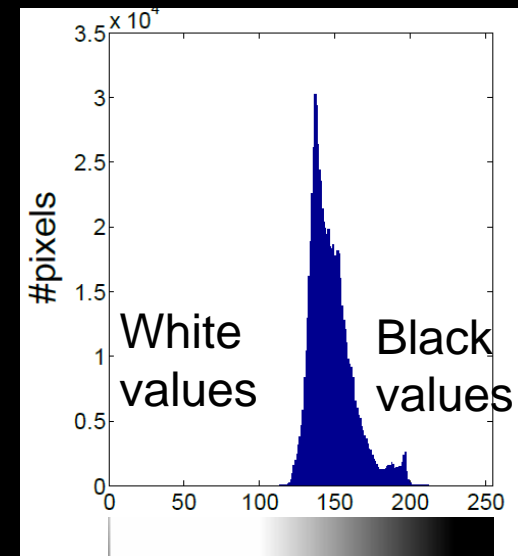
Image post processing

- Third, for-processing pixel values (Q_K) are modified to produce an image with values suitable for display (Q_P)
  - Computer auto detects collimator boundaries
    - Shutters remove white borders that cause veiling glare in eye
      - <u>Shutters should not be used to compensate for poor collimation</u>!
      - Exclude pixel values outside collimator boundaries

Images Courtesy of Stefan Specht, Philips
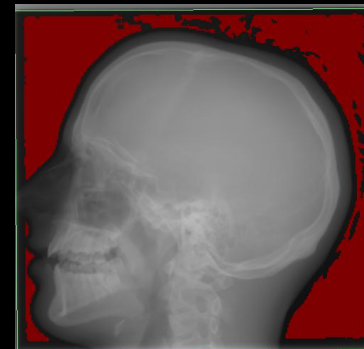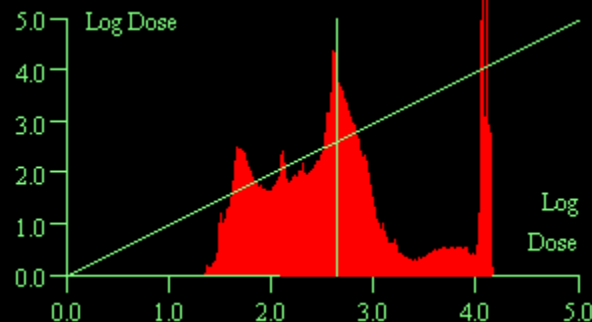
Image post processing

- Fourth, relevant anatomical areas of the radiograph are segmented
  - These points are called the values of interest (VOI)
  - e.g., lung parenchyma in chest x-ray; mediastinum tissue in thoracic spine, etc.
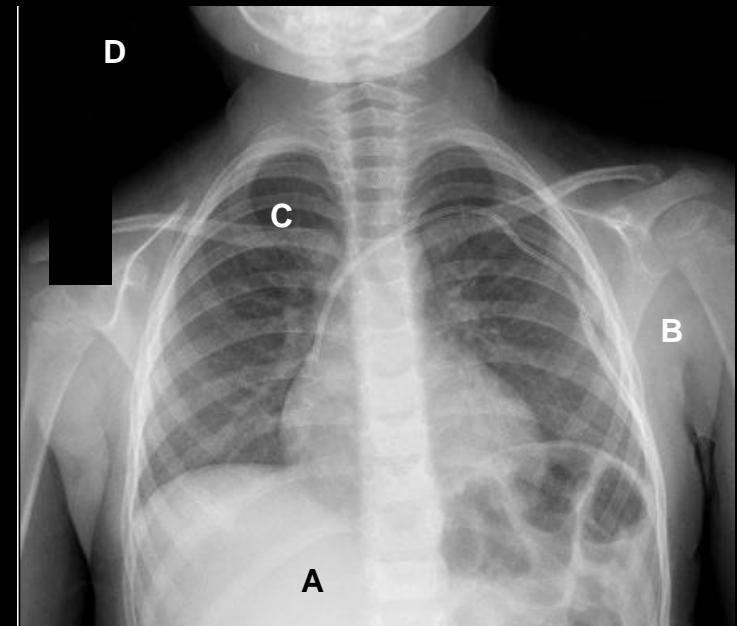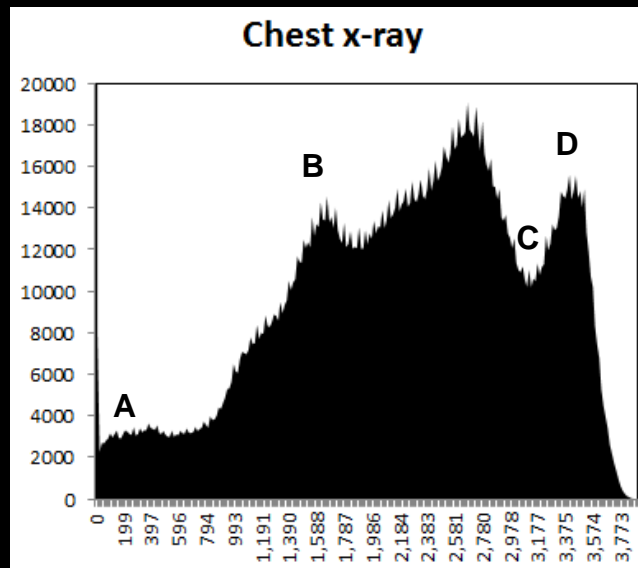
Image post processing

– Auto ranging function determines
  - relevant min and max pixel intensity values from the histogram
  - Sets VOI look up table (VOI LUT) with respect to histogram
  - VOI LUT maps digital densities to P-values for display
– Generally, histogram shapes are similar for similar anatomy
  - Important: select <u>correct body part view</u> before imaging patient
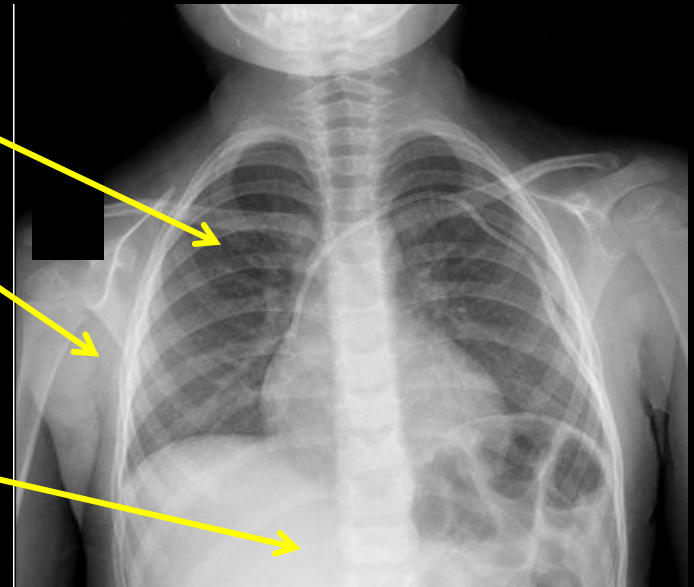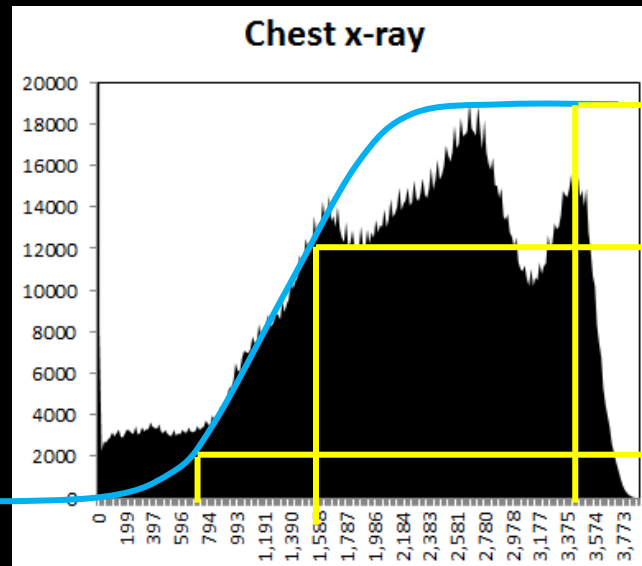
Image post processing

- Different VOI LUT may be optional and will affect image appearance

FB
FC
LIN
SCL
SWL
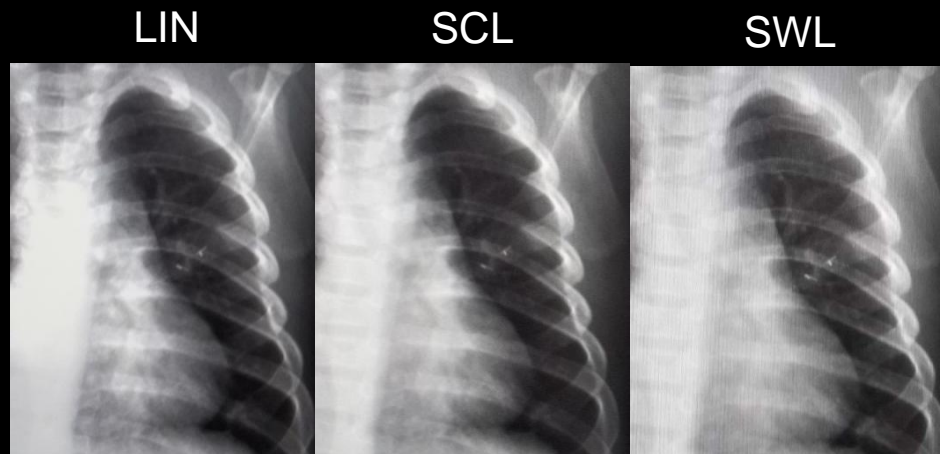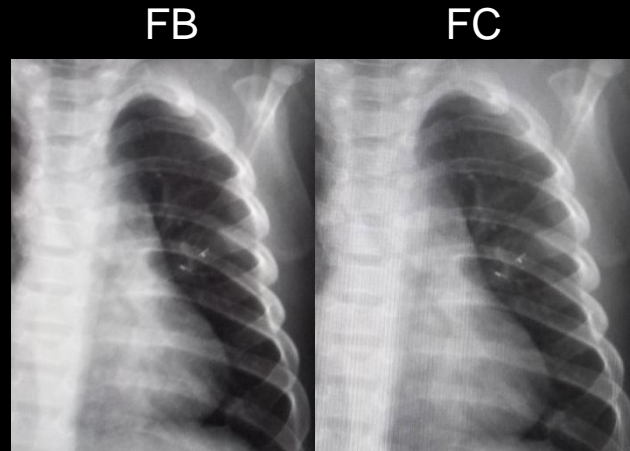
Philips

Image post processing

- Incorrect segmenting of histogram changes the look of the image
  - VOI LUT provides good contrast only for tissue of interest

Chest VOI   Soft Tissue VOI
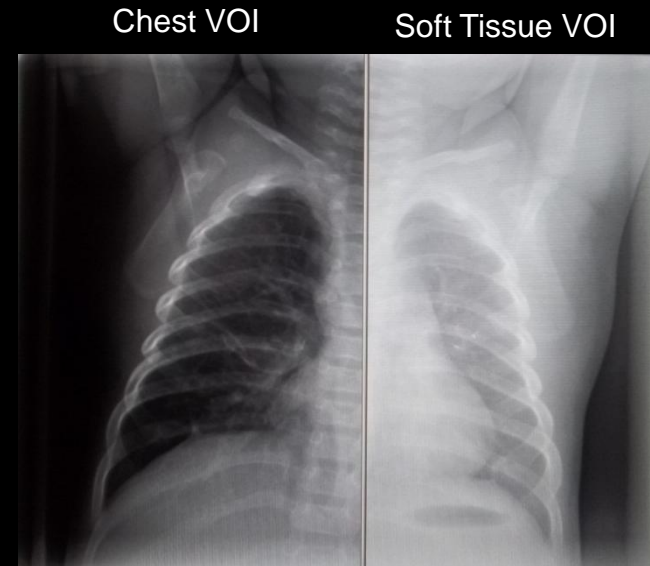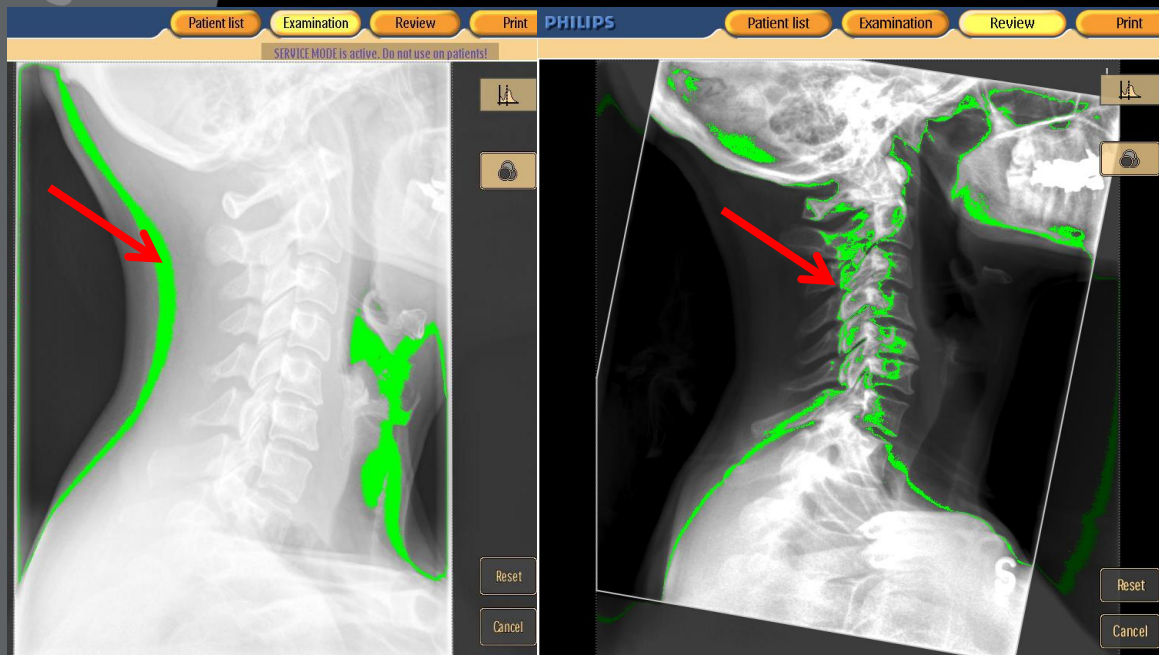
Images Courtesy of Stefan Specht, Philips
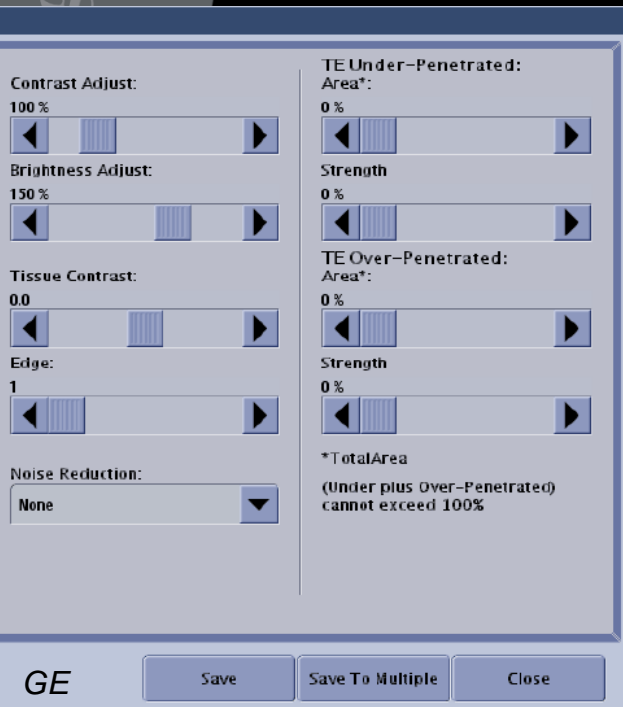
Image post processing

- Internal metal hardware, external fixators, restraining devices, Pb shilelds… confuse segmentation function
  - Set up separate processing algorithms for internal hardware
  - Close collimation (external hardware) reprocess then open up collimation

	Original knee	Knee w/ metal
Contrast Adjust	132%	147%
Brightness Adjust	140%	144%
Tissue Contrast	0.14	0.05
Edge	7	7
Under Penetration Area	20%	20%
Under Penetration Strength	20%	20%
Over Penetration Area	50%	60%
Over Penetration Strength	80%	30%

Original knee

Image post processing

- Fifth, Exposure index or air kerma index (K_{IND}) is determined from segmented anatomical areas (VOI)
  - K_{IND} relates the median exposure to these areas
    - NOT to whole image
    - Does not indicate an actual patient dose
  - IEC 62424-1/AAPM TG116 describe universal methodology
    - Deviation Index (DI)
- Patient dose vs. image post processing
  - Traditional screen-film served as type of exposure indicator
  - Digital radiography is forgiving of poor exposure
    - If exposure is < 50% ideal exposure, quantum mottle results
    - If exposure is > 200% ideal exposure, contrast loss results
      - "dose creep" occurs technologists increase exposure over time for better IQ

- Post processing order of operation
  - Segmentation
    - Make sure the correct anatomical protocol is selected
    - When possible, make sure the VOI is properly segmented
  - Apply the VOI LUT curve
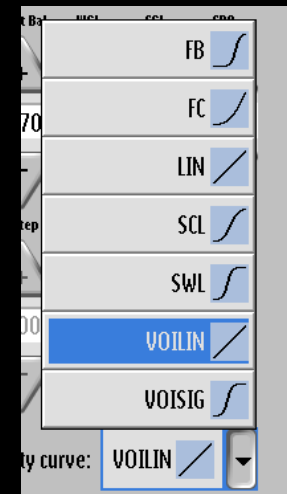
Image post processing: example

- Start by setting brightness (window level) and contrast (window width) of image

VOI LUT
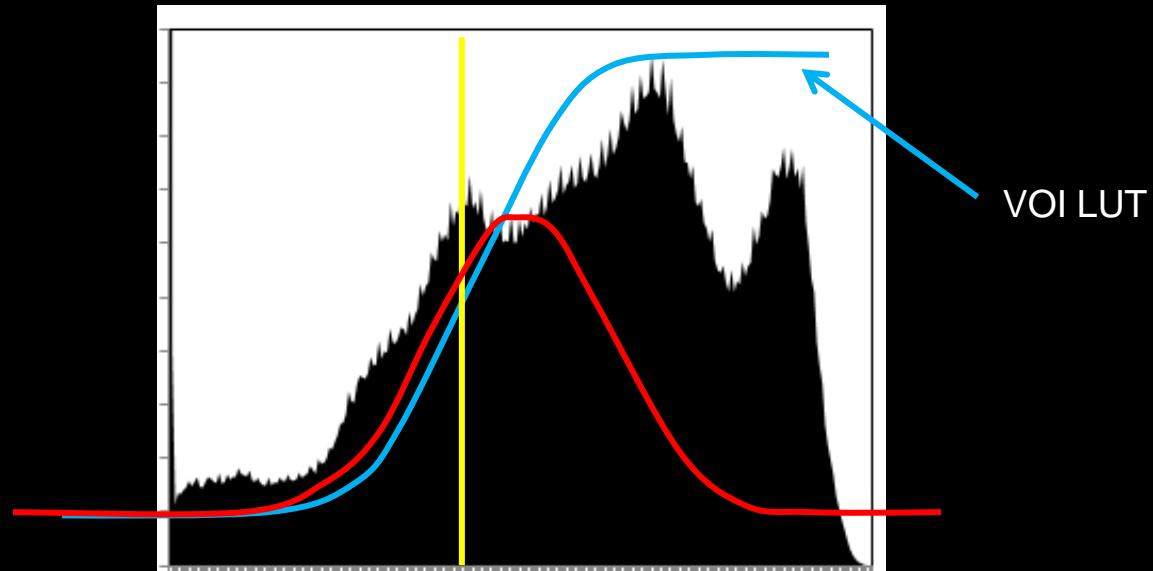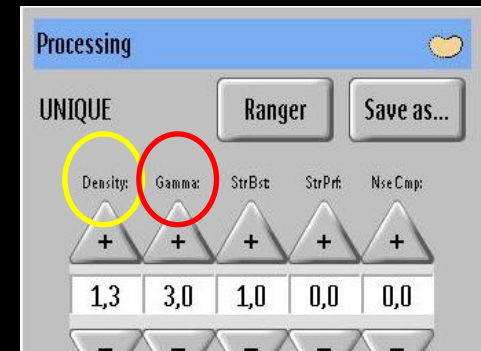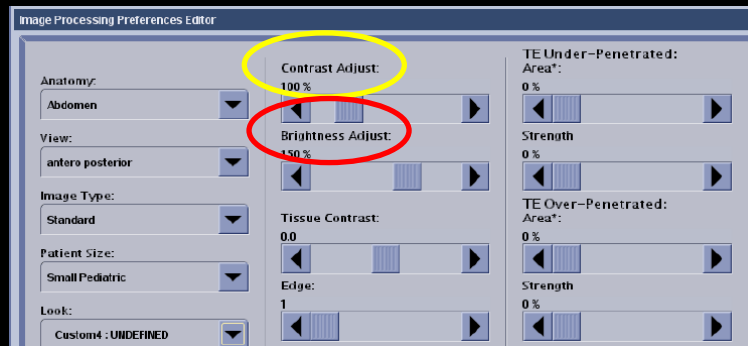
Image post processing: example

Brightness (window level)
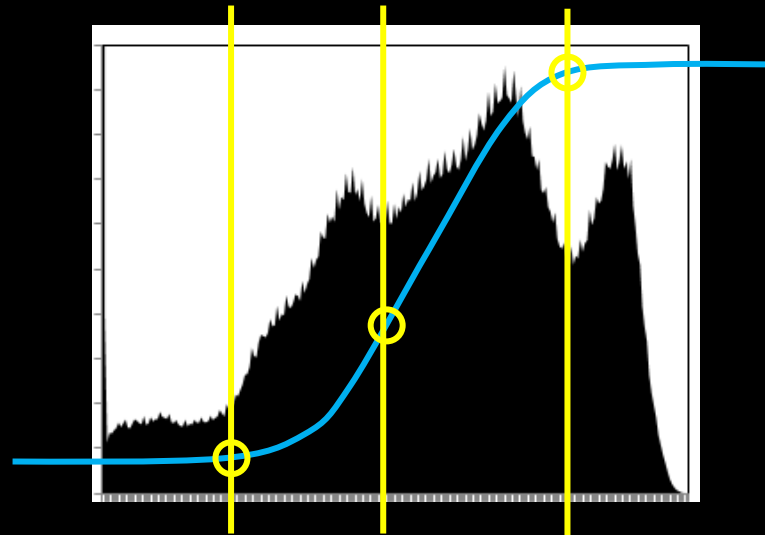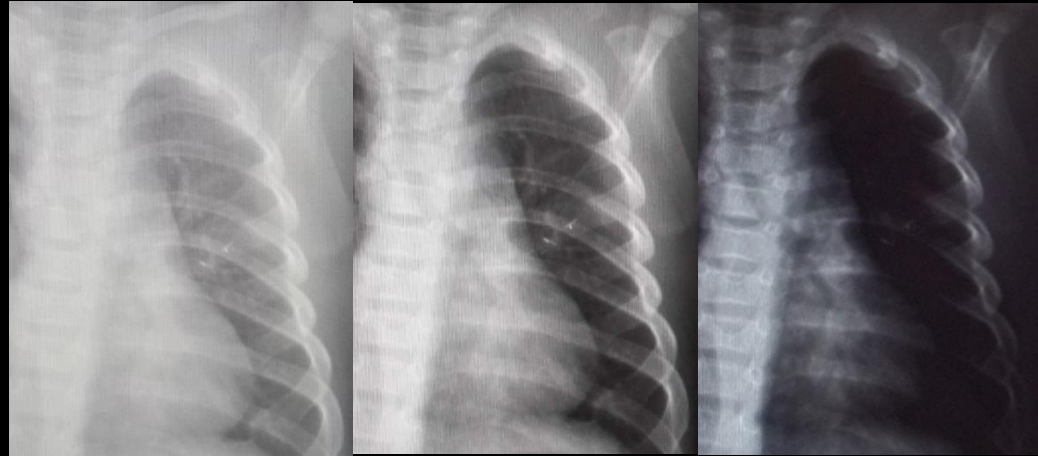
Image post processing: example

Contrast (window width)
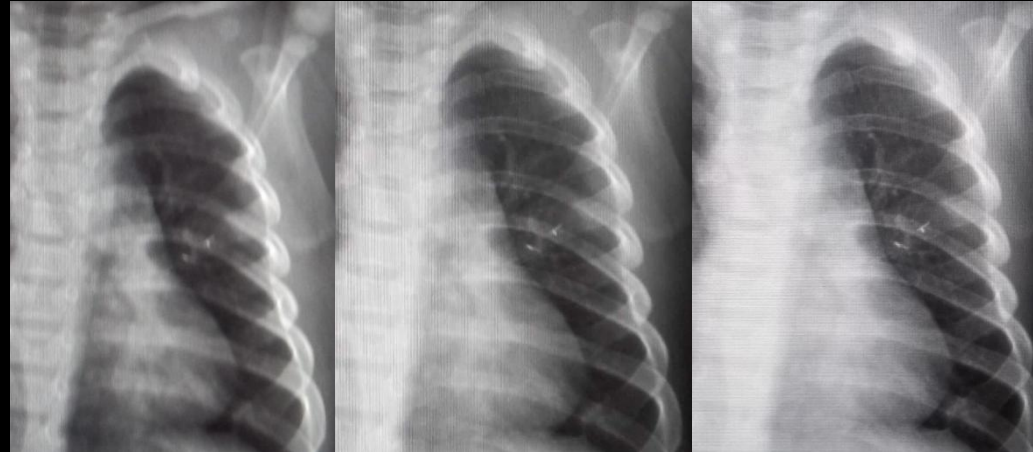
Image post processing: example

- Balancing contrast goals:
  - Enhances details in the white range
- If image is "too digital" increase contrast
  - Increased contrast = film like
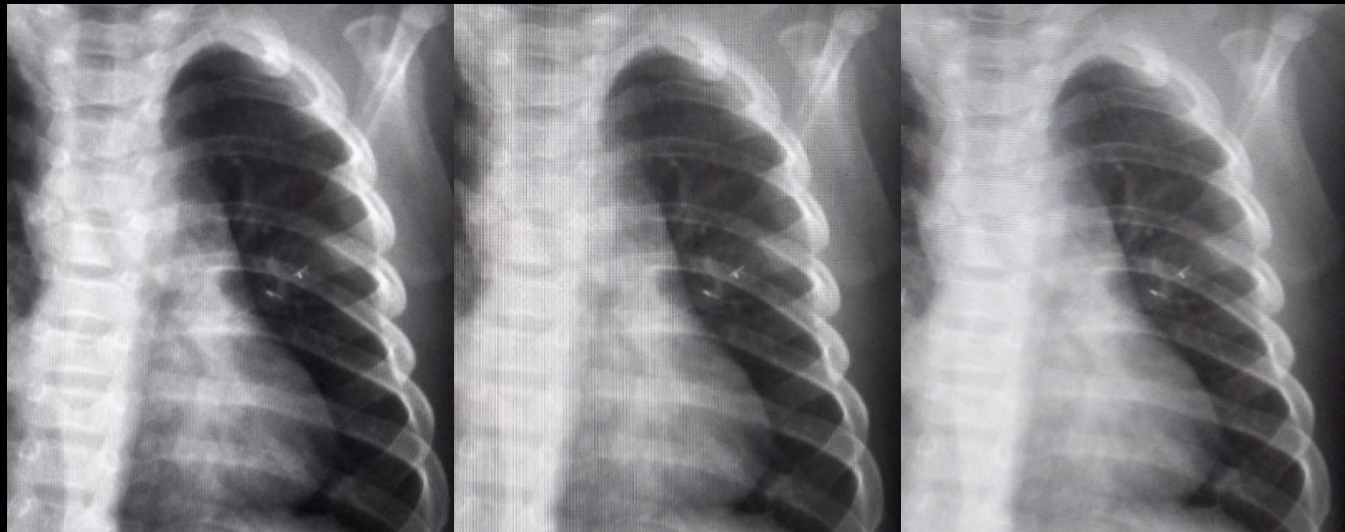
Image post processing: Recap

- Brightness (window level)
  - For this adjustment, only look at the image in the area of VOI
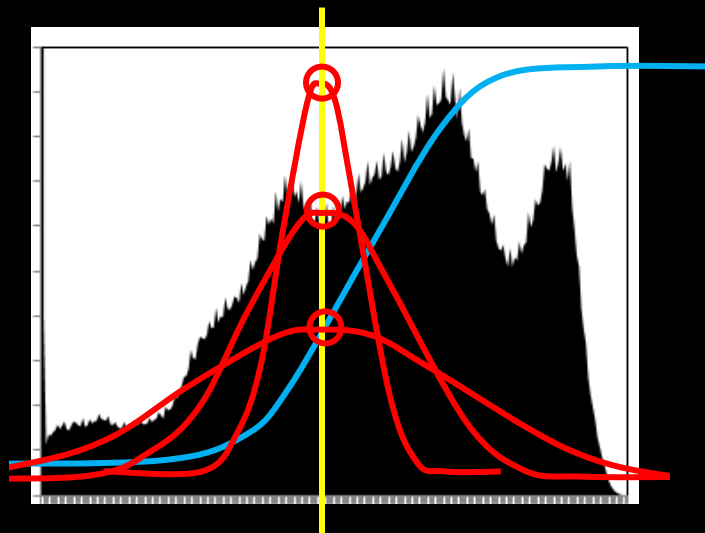 - Brightness (window level) is generally set a little higher for pediatrics than adults

Iterative process

- Contrast (window width)
  - Increase or decrease until it meets the radiologists expectations (i.e., visibility of soft tissue against bones)
  - Ped patients have poor internal contrast (no fat)
    » small adjustments make a big difference
  - Avoid clipping in all areas of the image

- Once you have a good base image then proceed with detail enhancement
  - Zoom image
    - De-magnified image does not show sub band 1 and presents as smoother than in reality

Image post processing: example

- Detail "edge" enhancement
  - Affects bony definition & noise
  - Pediatric radiologists generally accept more noise for more bony enhancement
    - Lower bone density for pediatric < 9 yrs old

No detail enhancement

Normalized for-processing pixel values (Q_K) are modified to produce an image with values suitable for display (Q_P) by first:

1. Segmenting image anatomy and establishing VOIs

2. Calculating the log transform of the raw image

3. De-noising image

4. Enhancing small detail structures

5. Converting pixel values to grayscale P-values
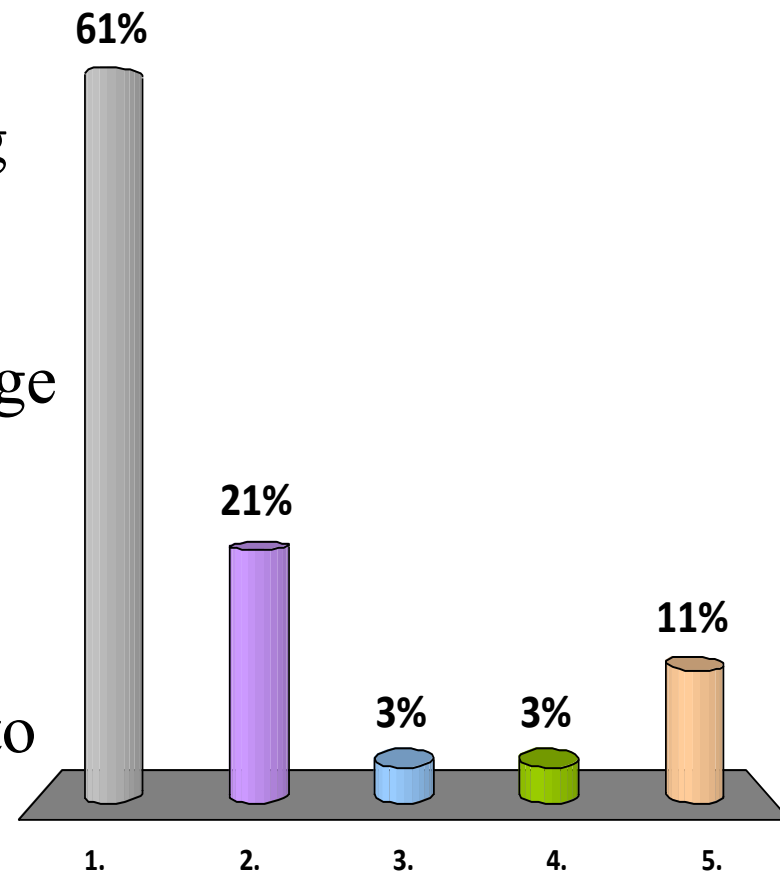
Answer

1. Segmenting image anatomy and establishing VOIs

Not all pixel values in an image are associated with objects that are of interest to the viewer for the purposes of diagnosis. Those that are of interest are referred to as the "values of interest" (or VOI). The pixels that are associated with the VOI are typically identified based on their physical location and their relative signal strength characteristics in the image histogram. This identification process is referred to as segmentation.

Reference: AAPM TG-116, P.6

A critical first step for digital radiographic post processing is:

1. Correcting the raw image for dark noise, gain, and bad pixels
2. Calibrating the monitor(s)
3. Establishing anatomical specific VOIs
4. Establishing a good quality low pass image for detail enhancement modification
5. Calibrating entrance exposure to detector for accurate exposure index (EI) calculation

Chart:
- 1. 35%
- 2. 38%
- 3. 13%
- 4. 5%
- 5. 8%
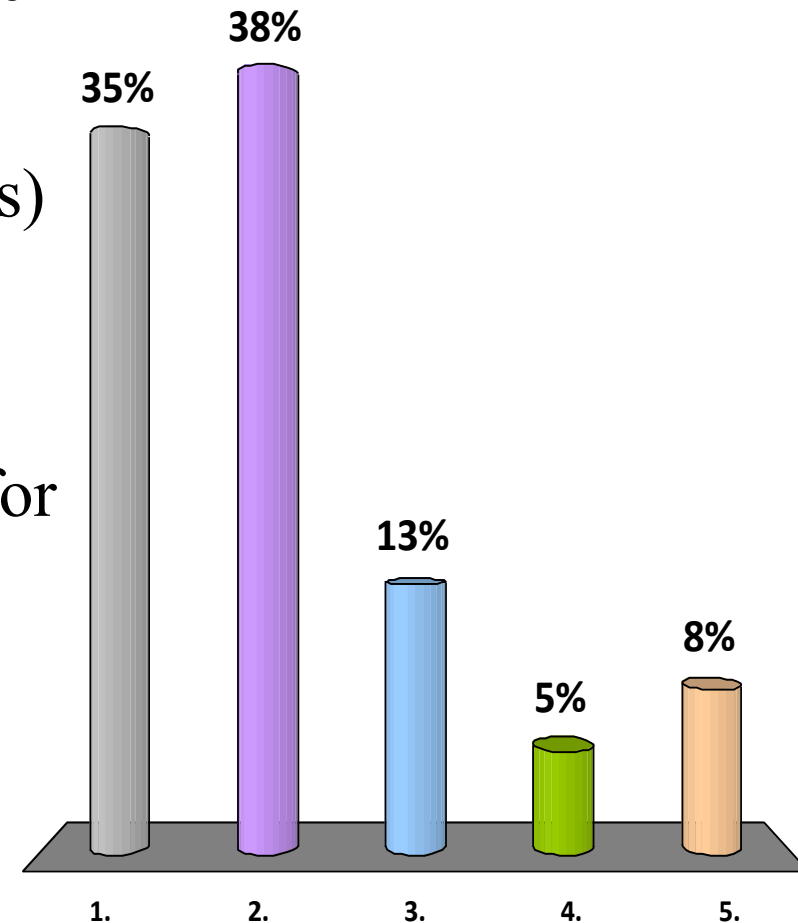
Answer

2. Calibrating the monitor(s)

Arguably this is my opinion, but if the DICOM calibration of the display monitor you are using to develop DR post processing techniques does not match the display from which your radiologist is reading, much of your work will be in vain (the both of you are seeing different things).

Selecting the proper anatomical acquisition protocol before acquiring the x-ray image is important because:

1. The proper kVp and mAs are anatomical specific
2. Post processing segmentation is based on histogram analysis that is anatomical specific
3. To set the proper filtration
4. To calculate exposure index (EI) accurately
5. Because post processing algorithms are age specific

50%   48%   0%   0%   2%
1.   2.   3.   4.   5.
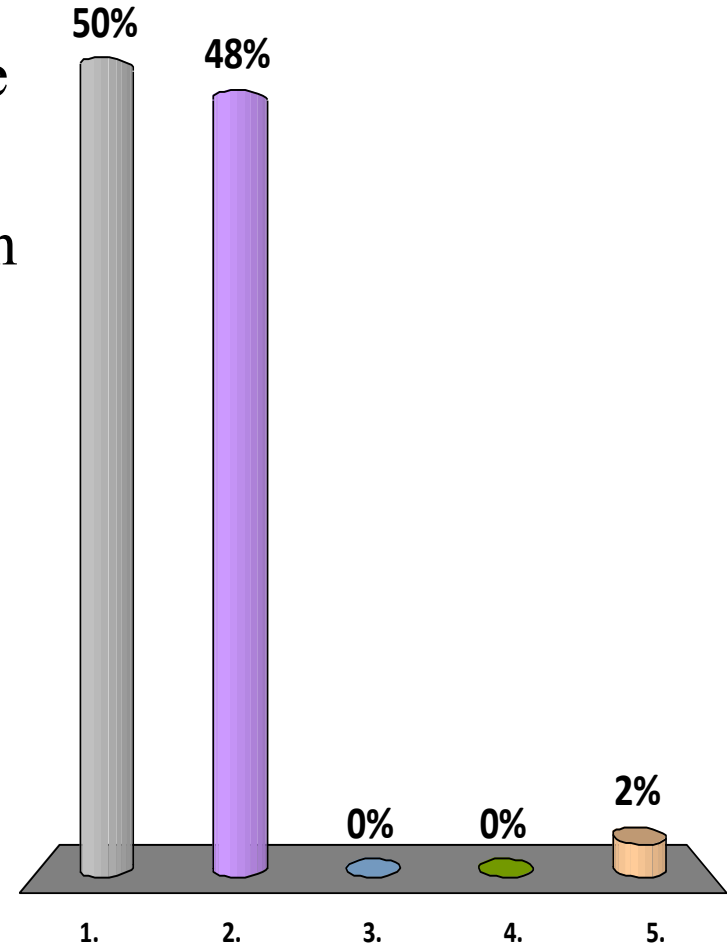
Answer

2. Post processing segmentation is based on histogram analysis that is anatomical specific

X-ray images are binned into a histogram whose general shape is anatomical specific. The overall location and magnitude of the histogram peaks are used to segment the image and apply the VOI LUT.

Reference: AAPM TG-116, P.12

Thank You!

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