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

St Jude Children’s Research Hospital

Samuel Brady, MS PhD DABR

samuel.brady@stjude.org
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 without 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
Default technique set up

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

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

- Adult
  - D1 = 1.5
  - D2 = 2.0

- Pediatric
  - D1 = 1.8
  - D2 = 2.1
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
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)
    
    \[ Q_K = 1000 \times \log_{10} \left( \frac{K_{STD}}{K_0} \right) \]

    - $Q_K$: 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; $K_{STD} \geq K_0$
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
• **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
      – Shutters should not be used to compensate for poor collimation!
      – Exclude pixel values outside collimator boundaries
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 correct body part view before imaging patient
Image post processing

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

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

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

<table>
<thead>
<tr>
<th></th>
<th>Original knee</th>
<th>Knee w/ metal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contrast Adjust</strong></td>
<td>132%</td>
<td>147%</td>
</tr>
<tr>
<td><strong>Brightness Adjust</strong></td>
<td>140%</td>
<td>144%</td>
</tr>
<tr>
<td><strong>Tissue Contrast</strong></td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Edge</strong></td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Under Penetration Area</strong></td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Under Penetration Strength</strong></td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Over Penetration Area</strong></td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Over Penetration Strength</strong></td>
<td>80%</td>
<td>30%</td>
</tr>
</tbody>
</table>
• **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
Image post processing: example

- 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
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

- **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
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
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
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!