Digital Imaging and ‘Dose Creep’

Images courtesy of Agfa Healthcare©


Gur et al., *Natural migration to a higher dose in CR imaging*, Proceedings of the Eight European congress of Radiology, 154 (1993)
Dose Tracking – Annual (Physicist)

- Tube Output, HVL
- Incident Air Kerma ($K_{a,i}$) Measurements
  - ‘typical’ doses
  - references for limits / reference levels:
    - NCRP 172
    - NEXT Surveys
    - State regulations
- AEC evaluation
  - EI is useful for this as well!
  - TEIs will be correlated w/ cutoff dose
- Accuracy of metric used for ongoing QC
  - DAP, EI, etc.
CCF Patient Incident Air Kerma (IAK)

• **GOAL:**
  - to reduce patient doses for common radiographic exams to below 3\textsuperscript{rd} quartile NEXT\textsuperscript{*} data for ALL sites

\textsuperscript{*}NEXT = National Evaluation of X-Ray Trends (CRCPD Pub. No. E. 03-2)
Where we were...

EXCEEDING NEXT 3rd QUARTILE
Where we were...

EXCEEDING NEXT 3rd QUARTILE
CCF Patient Incident Air Kerma (IAK)

- **HOW:**
  - kVp standardization for select exams
    - Enables comparison of IAKs between sites with *same* system
  - Development and documentation of image-based methodology for in-house AEC evaluation and calibration
  - Instituted new CCF limit for IAK
    - Identify outliers during annual testing

*NEXT = National Evaluation of X-Ray Trends (CRCPD Pub. No. E. 03-2)*
# CCF IAK Limits

<table>
<thead>
<tr>
<th>Grid Y/N</th>
<th>SID (cm)</th>
<th>AEC cell(s)</th>
<th>Dens</th>
<th>kVp</th>
<th>mAs</th>
<th>Patient Size (cm)</th>
<th>Measured Air Kerma @ SCD (mGy)</th>
<th>Incident Air Kerma $K_{a,j}$ @ SSD (mGy)</th>
<th>ODH Limit (mGy)</th>
<th>CCF Limit (mGy)</th>
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<tbody>
<tr>
<td>AP Abdomen</td>
<td>Y</td>
<td>102</td>
<td>LRC</td>
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<td>23</td>
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<td>C</td>
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<td>8</td>
<td></td>
<td>0.88</td>
<td>0.31</td>
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<td>PA-AP Chest*</td>
<td>Y</td>
<td>102</td>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td></td>
<td>0.35</td>
<td>0.26</td>
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<tr>
<td>PA-AP Chest*</td>
<td>N</td>
<td>102</td>
<td></td>
<td></td>
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<td>23</td>
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<td>PA-AP Chest</td>
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<td>182</td>
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<td>23</td>
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<td>0.35</td>
<td>0.26</td>
<td></td>
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</table>

* Measure for portables ONLY
# CCF IAK Limits

<table>
<thead>
<tr>
<th>Procedure</th>
<th>ODH Limit (mGy)</th>
<th>ODH Limit (mR)</th>
<th>CCF ESE Standard (mGy)</th>
<th>CCF ESE Standard (mR)</th>
<th>ESE Range quoted by ODH Min (mGy)</th>
<th>ESE Range quoted by ODH Max (mR)</th>
<th>NEXT Data Q3 (mGy)</th>
<th>NEXT Data Q3 (mR)</th>
<th>NEXT Data Av (mGy)</th>
<th>NEXT Data Av (mR)</th>
<th>TX Limit (mR)</th>
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<tbody>
<tr>
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<td>600</td>
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<td>490</td>
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<td>2.996</td>
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<td>2.996</td>
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<td>325</td>
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<td>1.75</td>
<td>200</td>
<td>1.183</td>
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<td>145</td>
<td>1.270</td>
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<td>1.270</td>
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<td>150</td>
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<tr>
<td>DP Foot</td>
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<td>100</td>
<td>0.31</td>
<td>35</td>
<td>8</td>
<td>35</td>
<td>0.158</td>
<td>18</td>
<td>0.114</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>PA-AP Chest w/ Gr</td>
<td>0.35</td>
<td>40</td>
<td>0.26</td>
<td>30</td>
<td>10</td>
<td>15</td>
<td>0.158</td>
<td>18</td>
<td>0.114</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>PA-AP Chest woo Gr</td>
<td>0.26</td>
<td>30</td>
<td>0.18</td>
<td>20</td>
<td>0.123</td>
<td>14</td>
<td>0.079</td>
<td>9</td>
<td>0.079</td>
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<tr>
<td>PA-AP Chest w/ Gr</td>
<td>0.35</td>
<td>40</td>
<td>0.26</td>
<td>30</td>
<td>10</td>
<td>15</td>
<td>0.158</td>
<td>18</td>
<td>0.114</td>
<td>13</td>
<td>30</td>
</tr>
</tbody>
</table>

NEXT = National Evaluation of X-Ray Trends  
CRCPD = Conference of Radiation Control Program Directors
References: *Diagnostic Reference Levels (DRLs)*

- ACR Practice Guideline for Diagnostic Reference Levels in Medical X-Ray Imaging. (Revised 2008, Resolution 3).
K_{a,i} - Limitations

- ‘Average’ patient doses do not necessarily reflect actual patient dose or the distribution in patient doses
  - Measurements do not indicate adherence to technique charts (manual)

- Phantoms represent a limited range of exam types and body parts

- Metrics are not suitable for ONGOING QC
  - Require a level of expertise (and equipment) to measure
Dose Tracking – Ongoing

Choose a Metric

Verify Indicator Accuracy

Establish Target Values

Develop Action Criteria

Education Education Education Education

Reporting Mechanism
Dose Tracking – Ongoing

WHAT INFORMATION IS AVAILABLE TO YOU??

- **Exposure Index**
  - DICOM tags*: EI(0018,1411), TEI (0018,1412), DI (0018,1413)
  - Available for all systems that have adopted IEC standard

- **Entrance Dose**
  - DICOM tags:
    - Entrance Dose (0040,0302)
    - Entrance Dose in mGy (0040,8302)
  - Available on systems with integrated generator

- **Area Dose Product**
  - DICOM tag:
    - Image and Fluoroscopy Area Dose Product (0018,115E)
  - Available on systems with integrated generator

*DICOM Correction item 1024 – ‘Exposure Index Macro’
Exposure Index \( (IEC\ 62494-1) \)

\[
EI = c_0 \cdot g(V)
\]

- Where
  - \( V \) is the \textit{Value of Interest}
  - \( g(V) \) is the inverse calibration function
  - \( c_0 = 100 \mu\text{Gy}^{-1} \)
Exposure Index

• **Advantages**
  - Reflects receptor dose
  - Not as dependent on patient size/distribution
  - Standardized metric

• **Disadvantages**
  - Indirectly related to patient dose
  - Depends on beam quality, exam/view, as well as vendor-defined VOI
  - Collimation, prosthetics, etc. can affect calculated value
Entrance Dose

- Incident air kerma ($K_{a,i}$) at a fixed location
  - Reference point varies among vendors
- Typically derived from exam parameters
  - kVp / mAs
  - not measured on a patient by patient basis
Entrance Dose

• **Advantages**
  - Can be used to estimate patient dose

• **Disadvantages**
  - No standard reference point or method for normalization
  - Entrance surface of patient may deviate from reference point
  - Does not represent size of the x-ray field

• **Most data from Europe**
  - But often limited to certain body habitus range
    - i.e. 65-75 kg, Hart 2003
  - Most US data currently w/ respect to phantoms
Image and Fluoroscopy Area Dose Product

- Product of the x-ray field size and air kerma
  - Dose Area Product (DAP)
  - Kerma Area Product (KAP)
  - Air Kerma-Area-Product ($P_{KA}$)
  - Unit DICOM field: dGy-cm²
- Often measured using a $P_{KA}$ meter installed on the collimator
Advantages
- Contains information about $K_{a,i}$ AND field size
  - Enables assessment of both patient dose and collimation
  - Field size can be derived if $K_{a,i}$ is known (or estimated)

Disadvantages
- DAP meter option may have to be purchased separately
- Difficult to isolate impact of collimation without knowledge of $K_{a,i}$
Dose Tracking – Ongoing

Choose a Metric

Verify Indicator Accuracy

Establish Target Values

Develop Action Criteria

Education Education Education

Reporting Mechanism
Exposure Index (IEC 62494-1)

- IEC 62494-1 standard states that the EI shall be calibrated such that:

  \[ EI = C_0 \cdot K_{CAL} \]

- Where
  - \( K_{CAL} \) is the receptor air kerma (in \( \mu \text{Gy} \)) under calibration conditions
  - \( C_0 = 100 \ \mu \text{Gy}^{-1} \)
Exposure Index (IEC 62494-1)

- Inverse calibration function is defined as:

\[ K_{CAL} = g(V_{CAL}) = f^{-1}(V_{CAL}) \]

- Inverse calibration function should have an uncertainty of less than 20%
Calibration Conditions (IEC 62494-1)

- Fixed radiation quality
  - RQA5
- Homogenous irradiation of image receptor
- Measurement of incident air kerma (free in air, no backscatter)
- Value of Interest (VOI) calculated from central 10% of image area for flat field images
Clinical Experience....

- 80 CR readers (Agfa)
- 38 units required PMT replacement (~50%)
PRIOR TO TESTING:
Mean = 0.853
SD = 0.233

53%Compliant
Post QC and Repair:

POST QC AND REPAIR:
Mean = 0.971
SD = 0.099
100% Compliant
Variation in Sensitivity

Variation in Reader Sensitivity over 6 Months

- ADC Compact
- ADC Compact Plus
- ADC Solo
- CR 25.0
- CR 75.0
- DX-G
- DX-S
### Exposure Index Verification and Uniformity

<table>
<thead>
<tr>
<th>Exam Tag</th>
<th>Delay</th>
<th>Filtration</th>
<th>SID</th>
<th>kVp</th>
<th>mAs</th>
<th>μGy (IP)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFPI</td>
<td>0 min</td>
<td>21 mm Al</td>
<td>150.0</td>
<td>75.0</td>
<td>10</td>
<td>20.3</td>
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</tbody>
</table>

* Value for double exposure w/ reported technique

<table>
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<tr>
<th>Plate Label</th>
<th>Plate ID</th>
<th>Size</th>
<th>IS/OOS</th>
<th>EI</th>
<th>P/F</th>
<th>Comments</th>
<th>Total Score</th>
<th>*</th>
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<tr>
<td>QC1</td>
<td>14” x 17”</td>
<td>IS</td>
<td>2150</td>
<td>P</td>
<td>150</td>
<td>Halo</td>
<td>0</td>
<td>E</td>
</tr>
<tr>
<td>1</td>
<td>14” x 17”</td>
<td>IS</td>
<td>2091</td>
<td>P</td>
<td>2</td>
<td>Cleaning streaks</td>
<td>2</td>
<td>OK</td>
</tr>
<tr>
<td>3</td>
<td>14” x 17”</td>
<td>IS</td>
<td>2255</td>
<td>P</td>
<td>1</td>
<td>Suction cup marks</td>
<td>1</td>
<td>G</td>
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<td>5</td>
<td>14” x 17”</td>
<td>IS</td>
<td>2148</td>
<td>P</td>
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<td>Smudges / Watermarks</td>
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<td>E</td>
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<td>7</td>
<td>14” x 17”</td>
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<td>2046</td>
<td>P</td>
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<td>Scratches or Cracks</td>
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<td>8</td>
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<td>2177</td>
<td>P</td>
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<td>2336</td>
<td>P</td>
<td>1</td>
<td></td>
<td>1</td>
<td>G</td>
</tr>
</tbody>
</table>

* E = Excellent condition (score of 0), G = Good (1), OK = Adequate (2), RFS = Remove from service (score ≥3)

**Expected EI:** 2028

**Plate Average:** 2103

**Tolerance Criteria (Single Plate) EI:**
- Min: 1682.7
- Max: 2524

**Tolerance Criteria:**
- ±20% of plate average
- COV<±10% across all plates

**SD in Sensitivity:** 109.0

**COV:** 5.2%
Exposure Indicator Accuracy (computed radiography)

- How well matched should my readers be?
  - ±25% should be achievable
  - TG-10 recommends readers be matched within ±10%
  - Can adjust the high-voltage settings on some units
  - In other cases have to replace the PMT
Indicator Accuracy

- **EI**
  - ± 20% - *IEC 62494-1*
- **P_{KA}**
  - ± 35% - *IEC 60601-2-43*
  - For $P_{KA} > 2.5 \text{ Gy-cm}^2$
- **K_{a,i}**
  - Vendor-defined
Dose Tracking – Ongoing

1. Choose a Metric
2. Verify Indicator Accuracy
3. Establish Target Values
4. Develop Action Criteria
5. Education Education Education
6. Reporting Mechanism
Establishing TEI Values

- DI is only useful if you have selected a reasonable TEI
- Some vendors will provide recommended TEI values
<table>
<thead>
<tr>
<th></th>
<th>kVp</th>
<th>Grid?</th>
<th>Phantom</th>
<th>Target $K_a$ (µGy)</th>
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</thead>
<tbody>
<tr>
<td>GE Flashpad (CsI)</td>
<td>80</td>
<td>No</td>
<td>20 mm Al</td>
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<tr>
<td>Siemens (CsI)</td>
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<td>No</td>
<td>0.6 mm Cu</td>
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<td>Agfa DX-D (CsI)</td>
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<td>No</td>
<td>25 mm Al</td>
<td>2.5</td>
</tr>
<tr>
<td>Philips</td>
<td>70</td>
<td>No</td>
<td>25 mm Al</td>
<td>2.5</td>
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<tr>
<td>Carestream DRX1-C</td>
<td>80</td>
<td>--</td>
<td>0.5 mm Cu + 1.0 mm Al</td>
<td>2.5</td>
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<tr>
<td>Canon CXDI-70C</td>
<td>80</td>
<td>Yes</td>
<td>20 cm PMMA</td>
<td>2.5</td>
</tr>
</tbody>
</table>

- Can calculate expected EI or PV for target $K_a$ under AEC calibration conditions
AEC Calibration and EI

• VOI can matter
  - Make sure to use the appropriate exam tag
  - Know the VOI used for EI calculation

• If using a target EI:
  - Must verify accuracy of exposure indicator and account for it

  - For CR
    • Time between image and readout must be kept consistent
    • Use QC plate or plate of median sensitivity
Establishing TEI Values

• The fewer sub-groups you have, the easier your TEI values are to implement…

• Our Agfa CR systems currently set up with three TEI sub-groups

• But are these right?
  • Chest (TEI – 350)
  • Non-Extremity (TEI – 400)
  • Extremity (TEI – 1000)
Entrance Air Kerma

- Still requires establishing a target value for it to be useful for ongoing QC
  - Individual values extremely dependent on patient size
  - No standardized method for normalization
  - Sample mean/median < a DRL
    - DRL specific to Exam
    - DRL should be adjusted to account for patient distribution OR
    - DRL evaluation should be limited to specific weight category (difficult to automate this!)
Dose Tracking – Ongoing

Choose a Metric

Verify Indicator Accuracy

Establish Target Values

Develop Action Criteria

Education Education Education

Reporting Mechanism
Setting Action Criteria

- Shape of distribution
- Expected variation
EI - Patterns

• Typically, 95% within +/- 2 DI
• SD in EI increases when manual techniques are used
• Log-normal distribution of EI
• Normal distribution of DI
  - SD in DI is independent of TEI
• Guidelines yet to be published
• Questions still to be answered:
  - What is a typical (acceptable) level of variation in the EI and DI
  - Are recommended TEI values optimized?
### Color Coded Exposure Bar Ranges

- **Green (Go)**
  - DI between -3 to +3 deviation units (aim 0)
  - Represents less than a 2x change (±) in exposure index from target
  - Images should be acceptable for exposure (no additional review required)

- **Yellow (Caution)**
  - DI between -6 and -3 or +3 and +6 Deviation Units
  - Represents a 2x to 4x change (±) in exposure index from target
  - Images may be under or overexposed, but could still be acceptable for use
  - Further review with supervision may be required to determine if repeat is needed

- **Red (Alert)**
  - DI < -6 or > +6 deviation units
  - Represents a greater than 4x change (±) in exposure index from target
  - Images are probably significantly under or overexposed and are not acceptable
    - Technique settings and targets should be checked
    - Images should be reviewed with supervision and repeated (as needed)

*Table provided courtesy of Agfa HealthCare.*
Dose Tracking – Ongoing

1. Choose a Metric
2. Verify Indicator Accuracy
3. Establish Target Values
4. Develop Action Criteria
5. Education
6. Reporting Mechanism
IEC Exposure Index

- **EI = Exposure Index**
  - Approximate exposure to the plate
  - LINEAR with exposure
    - Double the mAs, EI doubles

- **TEI = Target Exposure Index**
  - ‘Ideal’ exposure to the plate

- **DI = Deviation Index**
  - How far above/below the TEI you are
Deviation Index (IEC 62494-1)

\[ DI = 10 \cdot \log\left(\frac{EI}{EI_T}\right) \]

- A DI of 0 indicates the exposure was at the target value.
- ±1 DI = ~ ±25% difference in exposure, or +1/-1 density on a phototimer.
- +3 DI = 2x the target exposure.
- -3 DI = ½ the target exposure.
# TG-116 Recommendations

## Table 2. Exposure Indicator DI Control Limits for Clinical Images

<table>
<thead>
<tr>
<th>DI</th>
<th>Range Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; +3.0</td>
<td>Excessive patient radiation exposure  Repeat only if relevant anatomy is clipped or “burned out” Require immediate management follow-up.</td>
</tr>
<tr>
<td>+1 to +3.0</td>
<td>Overexposure: Repeat only if relevant anatomy is clipped or “burned out”</td>
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<tr>
<td>-0.5 to +0.5</td>
<td>Target range</td>
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<tr>
<td>Less than -1.0</td>
<td>Underexposed: Consult radiologist for repeat</td>
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<tr>
<td>Less than -3.0</td>
<td>Repeat</td>
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# Deviation Index

<table>
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<tr>
<th>Exposure</th>
<th>Deviation Index - DI</th>
<th>Correction Needed</th>
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</thead>
<tbody>
<tr>
<td>Over Exposed</td>
<td>6</td>
<td>Repeat if Image Saturated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce mAs 0.25x*</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>Caution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decrease mAs 0.5x*</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>None</td>
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<td>Aim</td>
<td>1</td>
<td>None</td>
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<tr>
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<td>-1</td>
<td>None</td>
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<tr>
<td></td>
<td>-2</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>&lt;-3</td>
<td>Possible Repeat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase mAs 2x*</td>
</tr>
<tr>
<td>Under Exposed</td>
<td>-6</td>
<td>Repeat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase mAs 4x*</td>
</tr>
</tbody>
</table>

*If needed based on image quality or dose*

Table provided courtesy of Agfa HealthCare.
Exposure Index

Deviation Index

@Target Exposure:

EI = 389 (~ 400)
DI = -0.1 (~ 0)

75 kVp, 6.3 mAs
Exposure Index (EI) = 204 (~ 200)
Deviation Index (DI) = -2.9 (~ -3)

EI > -3 = green

75 kVp, 3.2 mAs

½ mAs:
EI = 204 (~ 200)
DI = -2.9 (~ -3)
Exposure Indices

- Remember, clinical exposure indices will vary with
  - Manufacturer (different VOIs)
  - Anatomical view
  - Collimation
  - Exposure indicator accuracy

- Manual techniques will have larger variation than photo-timed exams

- Errors in detecting collimation borders can result in inaccurate calculation of EI
  - i.e. Merchant view for knees
Dose Tracking – Ongoing

1. Choose a Metric
2. Verify Indicator Accuracy
3. Establish Target Values
4. Develop Action Criteria
5. Education
6. Reporting Mechanism
Data Collection

Multiple Options…… (TG-151)

- Paper (single site)
- Modality Performed Procedure Step (MPPS report)
- RIS – extract and archive data (DICOM RDSR or MPPS)
- Send images to a separate server and strip data
Data Collection
Multiple Options…… (TG-151)

• Export data from workstation
  - Easiest option but not always packaged in a manner useful to the technologist
  - Need the option to export data in both formats
    • xml or csv
    • SIMPLE report for routine QC
  - Accidental or intentional deletion of data can occur (i.e. during software upgrade by service engineer)
Dose Tracking – Ongoing

1. Choose a Metric
2. Verify Indicator Accuracy
3. Establish Target Values
4. Develop Action Criteria
5. Education
6. Reporting Mechanism

RE-EVALUATE
## TEI vs. Exam Group

<table>
<thead>
<tr>
<th>Exam Group (k)</th>
<th>$N_k$</th>
<th>$D_{ref,k}$</th>
<th>Standard Error: $\Delta D_{ref,k}$</th>
<th>$D_{ref,k}$ Sub-Group</th>
<th>$K_{ref,k}$ Sub-Group</th>
<th>$TEI_k$ (TEI$_{ref}$= 400)</th>
<th>$TEI_k$ (TEI$_{ref}$= 350)</th>
<th>Weighted Average: $SD(D_{ref,k})$ 95% CI ($\pm DI$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>29078</td>
<td>-1.70</td>
<td>0.01</td>
<td>-2</td>
<td>0.6</td>
<td>252</td>
<td>221</td>
<td>0.79 (1.6)</td>
</tr>
<tr>
<td>Abdomen</td>
<td>3094</td>
<td>-1.30</td>
<td>0.03</td>
<td>-1</td>
<td>0.8</td>
<td>318</td>
<td>278</td>
<td>0.96 (1.9)</td>
</tr>
<tr>
<td>Abdomen GU</td>
<td>548</td>
<td>-1.24</td>
<td>0.03</td>
<td>-1</td>
<td>0.8</td>
<td>318</td>
<td>278</td>
<td>0.81 (1.6)</td>
</tr>
<tr>
<td>Mandible &amp; TMJ</td>
<td>145</td>
<td>-0.76</td>
<td>0.07</td>
<td>-1</td>
<td>0.8</td>
<td>318</td>
<td>278</td>
<td>1.21 (2.4)</td>
</tr>
<tr>
<td>Nasal &amp; Orbits</td>
<td>164</td>
<td>-0.63</td>
<td>0.08</td>
<td>-1</td>
<td>0.8</td>
<td>318</td>
<td>278</td>
<td>1.78 (3.5)</td>
</tr>
<tr>
<td>Spine</td>
<td>270</td>
<td>-0.51</td>
<td>0.05</td>
<td>0</td>
<td>1.0</td>
<td>400</td>
<td>350</td>
<td>2.26 (4.4)</td>
</tr>
<tr>
<td>C-Spine</td>
<td>7558</td>
<td>-0.37</td>
<td>0.01</td>
<td>0</td>
<td>1.0</td>
<td>400</td>
<td>350</td>
<td>1.01 (2.0)</td>
</tr>
<tr>
<td>Abdomen GI</td>
<td>536</td>
<td>-0.05</td>
<td>0.08</td>
<td>0</td>
<td>1.0</td>
<td>400</td>
<td>350</td>
<td>1.58 (3.1)</td>
</tr>
<tr>
<td>Full Leg / Full Spine</td>
<td>2863</td>
<td>0.20</td>
<td>0.01</td>
<td>0</td>
<td>1.0</td>
<td>400</td>
<td>350</td>
<td>1.78 (3.5)</td>
</tr>
<tr>
<td>T-Spine</td>
<td>1792</td>
<td>0.27</td>
<td>0.02</td>
<td>0</td>
<td>1.0</td>
<td>400</td>
<td>350</td>
<td>1.07 (2.1)</td>
</tr>
<tr>
<td>Shoulder</td>
<td>11367</td>
<td>0.38</td>
<td>0.01</td>
<td>0</td>
<td>1.0</td>
<td>400</td>
<td>350</td>
<td>0.95 (1.9)</td>
</tr>
<tr>
<td>Femur Knee Leg</td>
<td>27529</td>
<td>0.59</td>
<td>0.02</td>
<td>1</td>
<td>1.3</td>
<td>504</td>
<td>441</td>
<td>1.02 (2.0)</td>
</tr>
<tr>
<td>Skull, Sinus &amp; Facial</td>
<td>465</td>
<td>0.89</td>
<td>0.06</td>
<td>1</td>
<td>1.3</td>
<td>504</td>
<td>441</td>
<td>0.98 (1.9)</td>
</tr>
<tr>
<td>L/S Spine</td>
<td>13172</td>
<td>0.94</td>
<td>0.02</td>
<td>1</td>
<td>1.3</td>
<td>504</td>
<td>441</td>
<td>0.82 (1.6)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>60</td>
<td>1.05</td>
<td>0.24</td>
<td>1</td>
<td>1.3</td>
<td>504</td>
<td>441</td>
<td>1.87 (3.7)</td>
</tr>
<tr>
<td>Pelvis &amp; Hip</td>
<td>10910</td>
<td>1.07</td>
<td>0.01</td>
<td>1</td>
<td>1.3</td>
<td>504</td>
<td>441</td>
<td>0.88 (1.7)</td>
</tr>
<tr>
<td>Lower Extremity</td>
<td>1124</td>
<td>2.08</td>
<td>0.03</td>
<td>2</td>
<td>1.6</td>
<td>634</td>
<td>555</td>
<td>2.68 (5.3)</td>
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<tr>
<td>Ankle &amp; Foot</td>
<td>20519</td>
<td>3.26</td>
<td>0.01</td>
<td>3</td>
<td>2.0</td>
<td>798</td>
<td>698</td>
<td>0.83 (1.6)</td>
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<tr>
<td>Humerus, Elbow &amp; Forearm</td>
<td>4400</td>
<td>4.10</td>
<td>0.03</td>
<td>4</td>
<td>2.5</td>
<td>1005</td>
<td>879</td>
<td>0.83 (1.6)</td>
</tr>
<tr>
<td>Hand &amp; Wrist</td>
<td>11345</td>
<td>4.35</td>
<td>0.01</td>
<td>4</td>
<td>2.5</td>
<td>1005</td>
<td>879</td>
<td>0.75 (1.5)</td>
</tr>
<tr>
<td>Upper Extremity</td>
<td>680</td>
<td>4.43</td>
<td>0.08</td>
<td>4</td>
<td>2.5</td>
<td>1005</td>
<td>879</td>
<td>2.08 (4.1)</td>
</tr>
</tbody>
</table>

*Assuming an initial TEI of 400 for all exam tags
References: Exposure Indices


Hart et al., The UK National Patient Dose Database: now and in the future, Br. J. of Radiol. 76 (2003), 361-65


References: $P_{KA}$

- Hart et al., The UK National Patient Dose Database: now and in the future, Br. J. of Radiol. 76 (2003), 361-65
- Nickoloff et al., Radiation Dose Descriptors: BERT, COD, DAP, and Other Strange Creatures, Radiographics, Vol. 28. No. 5, 2008
Cleveland Clinic

Every life deserves world class care.