Radiation Dose Optimization in General Radiography

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Dynamic Range in Conventional Film-Screen System

Diagram from Woodward (2011)
Digital Radiography: Exposure Factor Selection and ALARA.
Dynamic Range in Digital Imaging System

Diagram from Woodward (2011)
Digital Radiography: Exposure Factor Selection and ALARA.

Dynamic Range
Film-Screen vs Digital Imaging

Diagram from Seibert & Morin (2011)
The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population.
Under-exposure in
Digital Imaging System

Over-saturation in
Digital Imaging System
Over-saturation in Digital Imaging System

Film-Screen vs Digital Optimal Exposure Parameter

60 kVp  1 mAs

Conventional Film  Digital Image

Diagram from Cooper, Cohen, Piersall, Apgar (2011)
Quality assurance: using the exposure index and the deviation index to monitor radiation exposure for portable chest radiographs in neonates.
Quality assurance: using the exposure index and the deviation index to monitor radiation exposure for portable chest radiographs in neonates.
Wide Dynamic Range in Digital Radiography

Diagram from Cooper, Cohen, Piersall, Apgar (2011)
Quality assurance using the exposure index and the deviation index to monitor radiation exposure for portable chest radiographs in neonates.

| 60 kVp | 0.1 mAs | 60 kVp | 128 mAs |

Dose Creep

- Loss of visual cue in digital image
- High dose reward in good image quality
- Radiographer tend to give a higher exposure factor to ensure a good image quality
- Higher radiation dose is disposed to patient
Dose Creep

Exposure Index/Indicator (EI)

- Feedback on the relative exposure level of a digital radiograph
- Measurement of the air kerma at the detector surface
- Reflect the detector dose but not patient dose
- Indirect indication of the quality of a digital radiograph
- Varies between different vendors
### Exposure Indicator/Index in Different Vendors

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Exposure indicator name</th>
<th>Symbol</th>
<th>Units</th>
<th>Exposure dependence, X</th>
<th>Detector calibration conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CredoStream</td>
<td>Exposure index</td>
<td>EI</td>
<td>mRads</td>
<td>EI + 300 + 2X</td>
<td>80 kVp, 1.0 mm Al, 0.5 mm Cu, EI &gt; 2000 @ 1 mR</td>
</tr>
<tr>
<td>Agfa</td>
<td>Log of medium of histogram</td>
<td>logM</td>
<td>lRads</td>
<td>logM + 0.3 + 2X</td>
<td>400 speed class, 75 kVp @ 1.5 mm</td>
</tr>
<tr>
<td>Siemens</td>
<td>Exposure index</td>
<td>EXI</td>
<td>μGy</td>
<td>X(μGy) = EXI / 100</td>
<td>RQA5, 70 kV + 0.6 mm Cu, HVL = 6.8 mm Al S = 200 @ 1 mR</td>
</tr>
<tr>
<td>Fujifilm</td>
<td>S value</td>
<td>S</td>
<td>Unitless</td>
<td>200S + X (mR)</td>
<td>80 kVp, 3 mm Al &quot;total filtration&quot; S = 200 @ 1 mR</td>
</tr>
<tr>
<td>Philips</td>
<td>Exposure index</td>
<td>EI</td>
<td>Unitless</td>
<td>1000X (μGy)</td>
<td>RQA5, 70 kV + 21 mm Al, HVL = 7.1 mm Al</td>
</tr>
<tr>
<td>GE</td>
<td>Detector exposure index</td>
<td>DEI</td>
<td>Unitless</td>
<td>DEI = ratio of actual exposure to expected exposure scaled by technique and system parameters. Expected exposure values can be edited by user as preferences.</td>
<td>Not available</td>
</tr>
</tbody>
</table>

Table from Seibert & Morin (2011)
The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population.

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### Standardized Exposure Index

The International Electrotechnical Commission (IEC) 62494-1 and the American Association of Physicists in Medicine Task Group (AAPM TG) 116 have been working separately on standardization of exposure values. Both efforts have been a collaboration among physicists, manufacturers, and the Medical Imaging Technology Alliance (MITA) organization. The IEC published their standard in 2008 and AAPM TG issued their report in 2009.

Don et al (2010)
New Digital Radiography Standards Simplified for Radiologists and Technologists
IEC Standard

Exposure Index (EI)

\[ EI = 100 K_{\text{cal}} \]

Where \( K_{\text{cal}} \) is the image receptor air kerma in \( \mu \text{Gy} \) under the calibration conditions.

Linear proportional to the detector dose

Exposure Indicator/Index in Different Vendors

<table>
<thead>
<tr>
<th>Dose (( \mu \text{Gy} ))</th>
<th>Carestream (EI)</th>
<th>Agfa (LGM)</th>
<th>Siemens (EXI)</th>
<th>Fujifilm (S)</th>
<th>Philips (E)</th>
<th>IEC (EI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2351</td>
<td>2.86</td>
<td>2000</td>
<td>89</td>
<td>50</td>
<td>2000</td>
</tr>
<tr>
<td>10</td>
<td>2051</td>
<td>2.56</td>
<td>1000</td>
<td>177</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>5</td>
<td>1751</td>
<td>2.26</td>
<td>500</td>
<td>355</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>2.5</td>
<td>1451</td>
<td>1.96</td>
<td>250</td>
<td>710</td>
<td>400</td>
<td>250</td>
</tr>
</tbody>
</table>
Deviation Index (DI)

\[ DI = 10 \times \log_{10} \left( \frac{E_I}{E_{I_T}} \right) \]

Where \( E_{I_T} \) is the target exposure index which is the reference exposure obtained with an optimal exposure.
Limitation of Exposure Index
EI varying with the ROI selection

EI 232
EI 264
EI 101
EI 1284

Limitation of Exposure Index
EI varying with the ROI selection

EI 181
EI 273

EI depends on patient's anatomy
Limitation of Exposure Index
EI varying with the ROI selection

EI 102

EI always change with different ROI selection
Limitation of Exposure Index
EI depends on the beam spectrum

EI will change with different kVp and beam filtration under the same detector dose

Picture from Don et al [2010] New Digital Radiography Standards Simplified for Radiologists and Technologists

S  OW  
S  easonably  
chievable  

A L A R A
Collimation

- Reduce the patient dose
  - Total volume of body tissue irradiated is reduced with an appropriate collimation

- Improve the image quality
  - The amount of scatter radiation is reduced

Image capture from
http://www.upstate.edu/radiology/education/mna/radiography/scattercoll/
Collimation

- Image capture from http://www.upstate.edu/radiology/education/rsna/radiography/scattercoll/

Higher kVp

- Reduce the Entrance Skin Dose
  - Higher average beam energy will reduce the amount of unnecessary low energy photon

- Image quality is not degraded
  - Digital imaging system can maintain a desired image contrast with the re-scaling in post image processing
Woodward (2011) Digital Radiography: Exposure Factor Selection and ALARA.

**kVp and ESD**

**60 kVp**  
7.4 mA

ESE 42.5 mR

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**kVp and ESD**

**64.5 kVp**  
5.67 mA

ESE 36.9 mR

Woodward (2011) Digital Radiography: Exposure Factor Selection and ALARA.
kVp and ESD

70 kVp  4.29 mAs
ESE 32.6 mR

81 kVp  2.74 mAs
ESE 27.3 mR

Woodward (2011) Digital Radiography: Exposure Factor Selection and ALARA.
**kVp and ESD**

Woodward (2011) Digital Radiography: Exposure Factor Selection and ALARA.

60 kVp  7.4 mAs  
ESE 42.5 mR

81 kVp  2.74 mAs  
ESE 27.3 mR

Another study of mean effective dose with varying kVp in the projection of AP pelvis

<table>
<thead>
<tr>
<th>kVp</th>
<th>Mean effective dose in mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>0.78</td>
</tr>
<tr>
<td>66</td>
<td>0.60</td>
</tr>
<tr>
<td>70</td>
<td>0.51</td>
</tr>
<tr>
<td>73</td>
<td>0.42</td>
</tr>
<tr>
<td>77</td>
<td>0.32</td>
</tr>
<tr>
<td>81</td>
<td>0.28</td>
</tr>
<tr>
<td>85</td>
<td>0.25</td>
</tr>
<tr>
<td>90</td>
<td>0.22</td>
</tr>
<tr>
<td>96</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Results from Grondin et al (2004)  
Dose-Reducing Strategies in Combination Offers Substantial Potential Benefits to Females Requiring X-ray Examination
Increase FFD/SID

- Reduce the Entrance Skin Dose
  - The proportion of Source to Image Distance (SID) to Source to Skin Distance (SSD) is decreased
    \[ ESD \propto \frac{(SID)}{(SSD)^2} \]

- Image quality is potential improved
  - Decreased image magnification can potentially yield a better spatial resolution of image

FFD/SID and ESD

<table>
<thead>
<tr>
<th>FFD/SID</th>
<th>ESE (mR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>81 kVp</td>
<td>8.94 mAs</td>
</tr>
<tr>
<td>40&quot; SID</td>
<td>ESE 108 mR</td>
</tr>
<tr>
<td>81 kVp</td>
<td>11.0 mAs</td>
</tr>
<tr>
<td>48&quot; SID</td>
<td>ESE 87.9 mR</td>
</tr>
</tbody>
</table>

Woodward (2011) Digital Radiography: Exposure Factor Selection and ALARA.
FFD/SID and ESD

Another study of mean effective dose with varying FFD in the projection of AP pelvis

<table>
<thead>
<tr>
<th>FFD in cm</th>
<th>Mean effective dose in mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.15</td>
</tr>
<tr>
<td>110</td>
<td>1.08</td>
</tr>
<tr>
<td>120</td>
<td>0.85</td>
</tr>
<tr>
<td>130</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Results from Grondin et al (2004)
Dose-Reducing Strategies in Combination Offers Substantial Potential Benefits to Females Requiring X-ray Examination

Reference


Woodward A. Digital Radiography: Exposure Factor Selection and ALARA. The University of North Carolina at Chapel Hill, School of Medicine; 2011
Thank you