Optimization of Radiation Dose and Image Quality in Diagnostic Radiology—Digital and Screen-Film Imaging

Joel E. Gray, Ph.D.
Landauer, Inc.
Director of Technology
Mayo Graduate School of Medicine
Professor Emeritus

Keith J. Strauss, M.Sc.
Children's Hospital
Director, Radiology Physics and Engineering
Harvard Medical School

Question of the Day...
Do you know what your doses are?

NEXT Survey Results

<table>
<thead>
<tr>
<th>Exam</th>
<th>Min</th>
<th>Max</th>
<th>Max/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA Chest</td>
<td>2.4</td>
<td>81</td>
<td>33.8</td>
</tr>
<tr>
<td>AP L. Spine</td>
<td>62</td>
<td>2,154</td>
<td>34.7</td>
</tr>
<tr>
<td>GI Exams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate</td>
<td>0.7</td>
<td>16.2</td>
<td>23.1</td>
</tr>
<tr>
<td>Spot Film</td>
<td>38</td>
<td>4,815</td>
<td>126.7</td>
</tr>
<tr>
<td>CT Head</td>
<td>1,600</td>
<td>14,000</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Reference Values (mrad)

<table>
<thead>
<tr>
<th>Exam</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA Chest</td>
<td>25</td>
</tr>
<tr>
<td>Cervical Spine</td>
<td>125</td>
</tr>
<tr>
<td>AP Abdomen and</td>
<td></td>
</tr>
<tr>
<td>AP Lumbar Spine</td>
<td>500</td>
</tr>
<tr>
<td>CT Head</td>
<td>6,000</td>
</tr>
<tr>
<td>CT Body</td>
<td>4,000</td>
</tr>
<tr>
<td>Fluoroscopic Rate</td>
<td></td>
</tr>
<tr>
<td>(per min)</td>
<td>6,500</td>
</tr>
<tr>
<td>Dental Bitewings</td>
<td>275</td>
</tr>
<tr>
<td>Cephalometry</td>
<td>25</td>
</tr>
</tbody>
</table>
**Is Dose the Only Concern?**

*NO!!!*

High doses usually mean poor image quality!

Low doses sometimes mean poor image quality!

---

**High Population Dose?**

<table>
<thead>
<tr>
<th>Exam</th>
<th>% Exams</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CED</td>
<td>39.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Chest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT Body</td>
<td>5.0</td>
<td>35</td>
</tr>
<tr>
<td>Angio*</td>
<td>1.2</td>
<td>22</td>
</tr>
<tr>
<td>GI</td>
<td>5.0</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>11.2</td>
<td>76</td>
</tr>
</tbody>
</table>

*Cardiac, Neuro, Vascular*

---

**Potential for Unlimited Exposure**

High Level Control (HLC)

Fluoroscopic Procedures

Any and All Digital Modalities

Computed Tomography

Computed Radiography

Digital Radiography

---

**Tackle Three Major Contributors First!!!**

Angiography

GI Examinations

Computed Tomography
Angiography, Fluoroscopy, and Radiography Dose Reduction

General Principles
- Increase HVL from 2.3 mm to >3.2 mm Al at 80 kVp
- Reduces exposure about 35% and dose about 25%
- No increase in tube loading
- No change in film density
- No loss of contrast

Increase tube potential
- An increase from 60 or 65 kVp to 70 or 80 kVp will reduce dose dramatically with only minor changes in contrast
- Contrast differences barely noticeable with kilovoltage differences of 5 to 10 kVp

Set a “floor” on kVp
- 80 kVp usually adequate for fluoro, except for pediatric patients
- 70 kVp adequate for most radiography, except for pediatric patients

Remove the grids!!
- Reduce the dose to 50%!!!
- Can remove grids for—
  - Small fields
  - Thin body parts
  - Low kVp, i.e., < 70-80 kVp
**Angiography Dose Reduction**

Number of images per run
- 1/sec during venous phase??
- How about 1@2, 1/sec, 1@2, 1@4?

Number of runs (like long fluoro times!!)
- Need full run?

*Digital image exposures similar to those from screen-film systems*

---

**Radiographic Dose Reduction**

High film density means high patient doses

- Optimize film processing
  - Proper time and temperature
  - Use chemistry, etc. recommended by film manufacturer
  - Mix chemistry in-house

---

**Radiographic Dose Reduction**

- Increase source-to-image distance
  - 40” to 48” yields about 8% reduction

- Use 0.6 mm focal spot!!

- Improves image sharpness

---

**Mayo Clinic Exposures**

- AP Lumbar Spine
  - NEXT Median = 333 mR
  - 1 Q = 252 mR
  - 3 Q = 487 mR
  - Mayo Clinic = 225 mR
Mayo Fluoro Exposure Rates

PA Abdomen

NEXT Median = 5.0 R/min
1 Q = 3.5 R/min
3 Q = 6.8 R/min
Mayo Clinic = 0.9 R/min

Pay Attention to Details

Dose Decrease

Optimized processing 12%
Increased SSD 10%
Fiber-interspaced grid 15%
Table-top transmission 15%

Results in a 43% reduction in patient dose!
Or 57% of initial dose!!!

Combined Potential Dose Reduction

Dose Decrease

Increased kVp 40%
Increased filtration 35%
Optimized processing 12%
Increased SSD 10%
Fiber-interspaced grid 15%
Table-top transmission 15%

Results in a 78% reduction in patient dose!
Or 22% of initial dose!!!

Screen-Film To Digital Conversion

Screen-film AP lumbar spine— 225 mR
Computed radiography AP lumbar spine— 225 mR

No Change!!
**CT Dose Reduction**

Adjust technique based on patient size and body part
Added filtration
No overlapping slices
Skip 0.5 to 1.0?

**Understand Protocols**

HS vs HQ???
High Speed vs High Quality??
In HQ mode mAs is reduced about 30%
Slice overlap
Increases doses 33% to 300%
Image quality for body CT— HS = HQ

**CT— Adjust Techniques**

Patient size—
Select technique based on equal noise level
Large patient images adequate?
Then reduce small patients by 8X
Large patient images noisy?
Increase large patients by 2X and reduce small patients by 4 X

**CT— Adjust Techniques**

Reduce techniques for specific body parts
Chest- 10 X (based on literature)
Imaging air
Chest x-ray is 15 mR
Lumbar spine is 300 mR— a 20X difference
Low vs High kVp Techniques

As you increase kVp the x-ray output increases, e.g. mR/mAs

Does this mean the dose increases?

For fixed mAs!!

Increase kVp, reduce mAs—
To produce same noise level
Reduce dose to patient

And Into the Future . . .

All digital modalities provide the potential for excessive patient exposures!!!

Insist on the use of automatic exposure control or strict adherence to technique charts

Monitor exposures on regular basis
Collimate to body part of interest

Noise Is Good!!

No noise— dose too high
Lots of noise— low dose, poor low contrast resolution
Some noise— optimized dose and image quality
Good Technique??

Reduce mAs for Same Noise

<table>
<thead>
<tr>
<th>kVp</th>
<th>13 cm</th>
<th>20 cm</th>
<th>25 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>50</td>
<td>350</td>
<td>800</td>
</tr>
<tr>
<td>100</td>
<td>25</td>
<td>180</td>
<td>450</td>
</tr>
<tr>
<td>120</td>
<td>19</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>140</td>
<td>12</td>
<td>75</td>
<td>200</td>
</tr>
</tbody>
</table>

Good Technique??

Noise Is Good!!

602 mR 295 mR

156 mR 64 mR
High Dose Exams—Summary

Do you know what your doses are?
Two important things—
- Image quality and dose
- *Noise is Good!!*
- Caveat emptor!!
- CT is a *High Dose* exam

Pay attention to details
Adjust techniques
Body size and part
No overlapping slices!!
Understand CT protocols

Use high kVp techniques
CT fluoro is exceedingly high dose rate
- Use intermittent mode—
  - Scan, look, adjust, scan...
Digital imaging has potential for unlimited dose!!
Reference values are the key
*Noise is good!!*
A Medical Physicist Can Save You More Than Just Your Money