A Review of Technical Motivations Behind Discontinuing Gonadal Shielding

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Introduction

• Define gonadal shielding
• Dose reduction of ‘ideal’ shielding
  • Impact of additional filtration in x-ray beam
  • Depth of the gonad
• Factors that reduce effectiveness of ‘ideal’ shields?
  • Scatter radiation
  • Challenges of gonadal shield positioning and negative impact on ‘ideal’ shielding
• Radio-Sensitivity of the gonads?
What is Gonadal Shielding?

• Placement of a shield, typically Lead equivalent material, on the surface of the patient to directly shadow and protect the male or female gonads from ionizing radiation beneath the shield.

• Practice began in the early 1950s.¹

Historical Perspective

• Radiation doses from diagnostic x-ray examinations are ~ 20 - 25\(^1\) times less radiation today: 1951 vs 2020

• Adult KUB: 1951 ~ 11 – 12 mGy\(^2\)
  2020 ~ 0.5 mGy air Kerma

• Newborn KUB: 1951 ~ 1.4 mGy\(^3\)
  2020 ~ 0.07 mGy air Kerma

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How Effective are Properly Aligned Gonadal Shields?
How Effective are Properly Aligned Gonadal Shields?

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation¹

- Three ATOM CIRS anthropomorphic Phantoms
  - Contain tissue equivalent major organs

<table>
<thead>
<tr>
<th></th>
<th>AP (cm)</th>
<th>LAT (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>23</td>
<td>32</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Newborn</td>
<td>9</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

- Three Circular shields equivalent to 0.5 mm Pb

<table>
<thead>
<tr>
<th></th>
<th>Radius</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>4.2 cm</td>
<td>55 cm²</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>3.6 cm</td>
<td>40 cm²</td>
</tr>
<tr>
<td>Newborn</td>
<td>2.5 cm</td>
<td>20 cm²</td>
</tr>
</tbody>
</table>

Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

- Clinical X-ray Field Areas

  - Adult male 1376 cm$^2$
  - 5 yr-old child 459 cm$^2$
  - Newborn 126 cm$^2$

Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

<table>
<thead>
<tr>
<th>Patient Age</th>
<th>kVp</th>
<th>mAs</th>
<th>Kerma (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>87</td>
<td>10</td>
<td>1.6</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>79</td>
<td>4</td>
<td>0.39</td>
</tr>
<tr>
<td>Newborn</td>
<td>77</td>
<td>2</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

- Added Filtration: 0.1 mm Cu + 1 mm Al

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<th>mAs</th>
<th>Kerma (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>87</td>
<td>16</td>
<td>1.2</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>79</td>
<td>6.3</td>
<td>0.28</td>
</tr>
<tr>
<td>Newborn</td>
<td>77</td>
<td>3.2</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

• Radiographic Techniques designed to deliver a constant entrance air Kerma to the image receptor for a given phantom

<table>
<thead>
<tr>
<th>Air Kerma (µGy) at Image Receptor</th>
<th>Entrance Air Kerma Reduction with Added Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>3</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>4.5</td>
</tr>
<tr>
<td>Newborn infant</td>
<td>6</td>
</tr>
</tbody>
</table>

Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

<table>
<thead>
<tr>
<th></th>
<th>Ovary (mGy)</th>
<th>Testes (mGy)</th>
<th>Ovary/Testes Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult male</td>
<td>0.54</td>
<td>1.81</td>
<td>30%</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>0.16</td>
<td>0.45</td>
<td>36%</td>
</tr>
<tr>
<td>Newborn infant</td>
<td>0.09</td>
<td>0.16</td>
<td>56%</td>
</tr>
</tbody>
</table>

Due to shielding of overlying soft tissue. Effect less for small patient.

Properly Aligned Adult Gonadal Shields

Dose map for Adult Phantom

- Ovaries ROI
- Testes ROI

Ovary level without Shield
- Ovary level with Shield

No Shield
- Ovary Shield
- Testes Shield

Testes level without Shield
- Testes level with Shield

Dose in mGy

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
Properly Aligned Gonadal Shields

Abdominal Doses with Gonadal Shields: Monte Carlo Simulation

- Standard Filtration with Shield

<table>
<thead>
<tr>
<th></th>
<th>Shielded Dose (mGy)</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ovary</td>
<td>Testes</td>
</tr>
<tr>
<td>Adult male</td>
<td>0.23</td>
<td>0.28</td>
</tr>
<tr>
<td>5 yr-old child</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>Newborn infant</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Why is effectiveness of shielding greater for the Testes as opposed to the Ovaries?

Properly Aligned Gonadal Shields

- Why is effectiveness of shielding always greater for the **Testes** as opposed to the **Ovaries**?
- As x-rays penetrate to greater depth, scatter radiation builds up as the primary x-rays scatter and are removed from the x-ray beam.
  - Scatter/Primary increases with Depth
  - **Phantoms**: $S/P = 1 - 1.5$ for Ovaries\(^1\)
  - $S/P = 0.6$ for Testes\(^1\)

Dose to unshielded Testes substantially due to primary while dose to Ovaries substantially due to scatter.

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Properly Aligned Gonadal Shields

- **Male**
  - Testes near surface and close together
  - Shield stops substantially all primary x-rays hitting it,
  - but none of scatter x-rays from outside the shielded area
  - One scattered x-ray of all drawn delivers dose to one of testes.
  - Testes tucked within protected region below the shield protects from all primary and most of scattered x-rays.
Properly Aligned Gonadal Shields

- Female
  - Ovaries near at mid depth and not necessarily on the midline.
  - Shield stops substantially all primary x-rays hitting it,
  - but none of scatter x-rays from outside the shielded area
  - Five scattered x-rays of all drawn deliver dose to the ovaries.
  - Ovaries are not effectively protected from increased levels of scattered x-rays at mid depth within the patient.
Alignment Affects Gonadal Shield Effectiveness

• Prior discussion is about ‘ideal’ performance of gonadal shields which is seldom clinically achieved . . .

• Why?
Alignment Affects Gonadal Shield Effectiveness

- Technologists use protocoled surface landmarks on the patient’s body to position gonadal shields,
- But, the actual location of the gonads varies greatly from patient to patient.
- Technologist is asked to perform a very difficult task.
- Gonads not fully covered 52% and 85% of the time for males and females respectively.\(^1\)

Alignment Affects Gonadal Shield Effectiveness

• Ideal Shielding:
  • 58% - 72% reduction for females
  • 85 – 90% reduction for males

Alignment Affects Gonadal Shield Effectiveness

• **Ideal Shielding:**
  - 58% - 72% reduction for females
  - 85 – 90% reduction for males

• **Misaligned Shielding:**
  - 2 cm: small effect for males, 10 – 40% loss of effectiveness for females

Alignment Affects Gonadal Shield Effectiveness\textsuperscript{1}

- **Ideal Shielding:**
  - 58\% - 72\% reduction for females
  - 85 – 90\% reduction for males

- **Misaligned Shielding:**
  - 2 cm: small effect for males, 10 – 40\% loss of effectiveness for females
  - 4 cm: substantially reduced effectiveness for children; area of shields smaller
  - Some remaining effect for adults.\textsuperscript{1}

Reconsidering the Value of Gonadal Shielding

- Believed reduced radiosensitivity of gonads
- ICRP 103:
  - Gonadal tissue weighting factor reduced: 0.2 to 0.08
  - Colon, stomach, liver, and bone marrow same at 0.12.
- Why are we shielding a less sensitive organ at the expense of more sensitive organs?
Reconsidering the Value of Gonadal Shielding

“Changing a ‘tradition’ is not easy. . .
Patients expect . . . the best care possible.
. . . care givers need to . . . help patients understand that their imaging experience should evolve to allow continued deliverance of the best care possible.”

Thank you

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