Radiation Dose Reduction: Should You Use a Bismuth Breast Shield?

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Breast Radiation on CT

- Use of chest CT has increased in women vulnerable to cancer induction by radiation.
- Radiation to the breast on CT pulmonary angiography may be 10-25 times higher than 2-view screening mammogram (2.4-5.0 mGy).
- Bismuth shield is designed to, and is proven to decrease breast exposure on CT.
Concepts

However, is there an alternative that can achieve an *equivalent reduced radiation exposure* with at least *equivalent image quality* on chest CT?
Methods

- Compared strategies of using Bismuth breast shield with standard radiation exposure factors vs. no shield with reduced mA.
- Chest region of an anthropomorphic phantom (CIRS Model 602), without and with Bismuth breast shield (AttenuRad, F&L Medical Products Co.)
  - Phantom alone
  - Phantom with 1 additional 3.5 cm simulated fat layer
  - Phantom with 2 additional 3.5 cm simulated fat layers
- GE Lightspeed 16
- 120 kVp, 0.8 sec rotation time, with Z-axis automatic exposure control
Methods

- Radiation exposure measured with ionization chambers in mediastinum and at surface.
  - Assumption: surface exposure = breast exposure
- mAs adjusted to achieve nearly equivalent standard deviations in the mediastinum without and with the shield.
- CT attenuation numbers recorded from:
  - Mediastinum
  - Superficial soft tissues
- Assumption: Standard deviation of HU of pixels (noise) in the usual area of diagnostic interest (mediastinum) should reflect image quality.
Validation of Noise-Exposure Relationship without Shield

- For mAs 424, measured SD = 7.31
- For mAs 239, calculation for SD:
  - $1/\sqrt{239/424} \times 7.31$
- Calculated SD at 239 mA = 9.74
- Measured SD at 239 mA = 9.70
- Confirms that noise differences for technique changes can be calculated - are not artifacts of reconstruction algorithm.
Results: Without and With Shield

- Effect on radiation exposure of using shield without modifying technique - constant mA.

<table>
<thead>
<tr>
<th></th>
<th>mA</th>
<th>Mediastinal SD</th>
<th>Dose Reduction-Surface</th>
<th>Dose Reduction - Mediastinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Shield</td>
<td>206</td>
<td>5.95</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>With Shield</td>
<td>206</td>
<td>7.40</td>
<td>31-37%</td>
<td>20-25%</td>
</tr>
</tbody>
</table>
Equivalent Radiation Without Shield

- What reduced mA *without* shield is *calculated* to result in noise (based on SD) in mediastinum similar to routine mA *with* shield?
- What reduced mA *without* shield *actually* achieves such noise?

<table>
<thead>
<tr>
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<th>Mediastinal SD</th>
<th>Dose Reduction-Surface and Mediastinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Shield - Calculated</td>
<td>134</td>
<td>7.40</td>
<td>35%</td>
</tr>
<tr>
<td>No Shield - Actual</td>
<td>120</td>
<td>7.33</td>
<td>42%</td>
</tr>
</tbody>
</table>
Equivalent Radiation Without Shield - One Added Fat Ring

- What reduced mA without shield is calculated to result in noise in mediastinum similar to routine mA with shield?
- What reduced mA (from 424) without shield actually achieves such noise?

<table>
<thead>
<tr>
<th>No Shield - Calculated</th>
<th>mA</th>
<th>Mediastinal SD</th>
<th>Dose Reduction-Surface and Mediastinum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>268</td>
<td>9.07</td>
<td>37%</td>
</tr>
<tr>
<td>No Shield - Actual</td>
<td>247</td>
<td>9.15</td>
<td>42%</td>
</tr>
</tbody>
</table>

Similar results with two added fat rings
Radiation at Surface

- In each case, using noise in mediastinum *with* shield to calculate what lower mA should be used *without* a shield suggests the need for a higher exposure than is necessary to achieve the same noise level.
- Therefore, noise is higher with a shield than one would expect based on the actual dose reduction.
- These higher noise levels with the shield are not visible as streak artifacts and may be the result of the geometric asymmetry and beam filtration of shield.
Radiation at Mediastinum

For equivalent *noise* within *mediastinum*, radiation dose reduction within *mediastinum*:

<table>
<thead>
<tr>
<th></th>
<th>No fat rings</th>
<th>One added ring</th>
<th>Two added rings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Shield, lower mA</strong></td>
<td>42%</td>
<td>41%</td>
<td>40%</td>
</tr>
<tr>
<td><strong>Shield, routine mA</strong></td>
<td>20-25%</td>
<td>18%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Hounsfield Unit Variation

Surface attenuation

<table>
<thead>
<tr>
<th>120 kVp</th>
<th>No fat rings</th>
<th>One added ring</th>
<th>Two added rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Shield</td>
<td>-5 HU</td>
<td>-69 HU</td>
<td>-69 HU</td>
</tr>
<tr>
<td>Shield</td>
<td>27 HU</td>
<td>-39 HU</td>
<td>-44 HU</td>
</tr>
</tbody>
</table>

- Attenuation in *mediastinum* varied ≤3 HU between shield, no shield
Streak Artifacts

- Shield creates streak artifacts, particularly marked at upper and lower edges.
Breast Exposure on Abdominal CT

- Breasts sometimes in field, depending on:
  - Technologist upper range
  - Diaphragm position
  - Breast size

- Concerns with using breast shield on abd CT:
  - Causes streaks through upper abdomen, particularly at edge of shield
  - Alters attenuation
Limitations of Study

- No information regarding what noise levels result in diagnostic examination.
- No measurement of spatial or contrast resolution.
- Study not performed in vivo.
- Only one scanner and one kVp tested.
Conclusions

- *Same* or *lower* noise in mediastinum can be obtained with the *same* or *lower* exposure to breasts without shield using a reduced mA as with shield using a baseline mA
  - Similar results with added simulated fat rings
- Substantially lower radiation to mediastinum with lower mA strategy without the shield
- Shield alters attenuation values
- Shield creates streak artifacts and incurs cost
Therefore, this phantom study suggests that reducing mA without a shield is more appropriate than using a shield with a standard mA to limit radiation dose to the breasts and mediastinum and to optimize image quality.
Conclusions - Abdominal CT

- Use of shield depends on:
  - Breast, diaphragm location
  - Patient comorbidities and age
  - Need for high-quality images through upper liver

- Other measures to limit breast radiation:
  - *Lead* apron or shield can protect from overranging if breasts not in field
  - Can keep bra on or retract breasts above field
Challenges

- Although several studies suggest that lower dose chest CT is diagnostically acceptable, there are no specific standards for appropriate mA for chest CT.
- Challenge is to design protocols and procedures that assure use of appropriately lower mA for chest CT in vulnerable women.
- Use of Bismuth or lead shield for abdominal CT depends on multiple factors