To Shield or Not to Shield?

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Disclosures

- Consultant to:
  - Nuance, Inc.
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.
• However, is there an alternative that can achieve an *equivalent reduced radiation exposure* with at least *equivalent image quality* on chest CT?

• What are the advantages and disadvantages of various strategies?
Our Phantom Study

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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, without and with Bismuth breast shield
  - Phantom alone
  - Phantom with 1 additional 3.5 cm simulated fat layer
  - Phantom with 2 additional 3.5 cm simulated fat layers
Methods

- 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
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>
<th></th>
<th>mA</th>
<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>
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 shield attenuation in both AP and PA orientations.
For equivalent *noise* within *mediastinum*, radiation dose reduction within *mediastinum*:

<table>
<thead>
<tr>
<th>No fat rings</th>
<th>One added ring</th>
<th>Two added rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Shield, lower mA</td>
<td>42%</td>
<td>41%</td>
</tr>
<tr>
<td>Shield, routine mA</td>
<td>20-25%</td>
<td>18%</td>
</tr>
</tbody>
</table>
Attenuation in *mediastinum* varied $\leq 3$ HU between shield, no shield

**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>
Shield creates streak artifacts, particularly marked at upper and lower edges.
Why Do We *Expect* the Shield to Work?

- Why is the use of shielding an attractive concept?
  - Use of lead shields ingrained in our training and seems intuitive

- However, fundamental difference:
  - Lead shields are intended to attenuate radiation for areas in patients or for people who are *not* being examined, but
  - Bismuth shields intended to limit radiation to areas that *are* being examined
Why Doesn’t the Shield Work?

- Shield attenuates photons both entering (from the front), but also exiting (through the front), wasting radiation
- Causes beam-hardening, streak artifacts, HU changes
Why Doesn’t the Shield Work?

- Does the shield selectively attenuate low-energy photons?

- No. Preinstalled filters attenuate low-energy photons before reaching the patient or shield. Spectrum from one manufacturer: mean photon energy of 69.1 keV for a 120-kV, but shields only increase the mean energy to 70.5 keV - 71.6 keV.

Why Doesn’t the Shield Work?

- May confuse AEC programs
  - If place shield before radiograph, AEC compensates with increased exposure
  - If place shield after radiograph, exposure is too low, decreasing image quality
  - If real-time AEC, then will partially compensate with increased exposure when shield in field, whether you put the shield on before or after scanogram
    - Do you know if your system has real-time AEC?
Why Doesn’t the Shield Work?

- Four other phantom studies all led to same conclusion:
Why Not Reduce Dose *and* Add Shield?

- Dose reduction is *linear* – proportional to mAs.
- Theoretical example:
  - Standard, no shield: 180 mA
  - 120 mA, no shield decreases breast dose 33%
  - 180 mA, with shield decreases breast dose 33%
- Theoretical reduced dose *plus* shield:
  - 120 mA, with shield, reduces dose to 44% of original
  - 80 mA, no shield also reduces dose to 44% of original, better noise, better sectional dose profile, no artifacts, etc.
Disadvantages of Shield

- *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 and remainder of region with lower mA without the shield
- Shield alters attenuation values
- Shield creates streak artifacts
  - In field: deep to shield
  - At upper and lower edges
  - Worse if any motion
Other Disadvantages of Shield

- Proper use depends on knowing how your manufacturer, model of scanner and version of software perform AEC
- Have to stop after scout and place the shield
- Costs money
- Need to use infection control techniques because comes in contact with patient
Recommendations – Chest CT

- Identify population of patients for whom decreased breast dose desired:
  - E.g. women under 50 yo, without terminal condition
- Reduce mA by 30%, do not use a shield
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
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
Recommendations – Abdominal CT

- Train and encourage technologists to limit “overranging”
- Keep bra on if not also scanning chest, attempt to retract breasts
- If possible, reduce mA 30% for upper component of abdominal scan
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 low-dose 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