Comparison of the function and performance of CT AEC systems

CTUG meeting
by
Emily Field
Trainee clinical scientist

14th October 2010
Breakdown

- CT Automatic Exposure Control (AEC)
  - Background
- Project Description
  - Aim
  - Methodology
  - Results
  - Conclusion

14th October 2010
What is the aim of AEC in CT?

- To minimise or remove variations in image quality between different images.
- To reduce variation in doses delivered to patients of varying sizes/shapes.

How is this achieved?

- This is made possible in CT scanning by controlling the tube current (mA) during scanning to achieve the required level of image noise. This is also known as mA modulation.

Modern CT scanners can achieve mA modulation in 3 distinct ways………
AEC systems in CT

1. Patient size AEC

- mA is adjusted grossly based upon the overall size of the patient.

- **Large Patient**
  - High mA

- **Small Patient**
  - Low mA
2. **Z-axis AEC**

- Variations in attenuation along the length of the patient are compensated for by adjusting the mA for each successive tube rotation.

![Diagram showing tube current and mA variation along the z-axis with different mA settings for Pelvis and Neck areas.](image)
AEC systems in CT

3. Rotational AEC

- mA is adjusted during a single rotation of the tube to compensate for differences in attenuation between AP and Lateral projections.
In reality, all three AEC systems operate simultaneously.

**Patient and z-axis AEC**
- The main source of patient attenuation data necessary for operation of the AEC system is acquired during the *scan projection radiographs* (SPRs). These are also known as scouts, topograms or scanograms.

**Rotational (x, y – axis) AEC**
- Feedback - changes in patient profile occur gradually along the z-axis, many systems utilise real-time feedback to inform the system of the changes in attenuation. For example, the patient attenuation data acquired during a single rotation can be used to inform the system of the optimum mA settings for the subsequent rotation.
- SPR - asymmetry of the patient can be estimated from SPRs and the x-ray tube current varied accordingly.
AEC systems in CT - Benefits

What are the overall benefits?

- **Consistent image quality** - User defined levels of image noise achievable from slice to slice but also from patient to patient.

- **Potential to reduce patient exposure** - A fully optimised CT system can avoid unnecessary exposure of the patient.

- **Reduced tube loading** - Modulated mA runs have the potential to reduce the overall loading of the x-ray tube.

- **Extended scan runs** - A reduction in x-ray tube heating means that longer scan runs can be utilised where necessary.

- **Reduction of photon starvation artefacts** - Rotational AEC means that previously under-sampled lateral projections (e.g. across shoulders) can be avoided.
AEC systems in CT

- Each major CT manufacturer has their own version of AEC.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Patient size AEC</th>
<th>Z-axis AEC</th>
<th>Rotational AEC</th>
<th>Method for setting exposure level</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>AutomA</td>
<td>AutomA</td>
<td>SmartmA</td>
<td>“Noise Index”</td>
</tr>
<tr>
<td>Siemens</td>
<td>Care Dose 4D</td>
<td>Care Dose 4D</td>
<td>Care Dose 4D</td>
<td>“Reference mAs”</td>
</tr>
<tr>
<td>Toshiba</td>
<td>Sure Exposure</td>
<td>Sure Exposure</td>
<td>Sure Exposure 3D</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>Philips</td>
<td>DoseRight ACS</td>
<td>-</td>
<td>DoseRight DOM</td>
<td>“Reference image” noise level</td>
</tr>
</tbody>
</table>

14th October 2010
Study Aim

To assess the efficacy of a range of CT scanner AEC systems using a homogeneous elliptical cone phantom. Variations in performance characteristics between scanner models and manufacturers was also investigated.
## Scanners Tested

<table>
<thead>
<tr>
<th>Hospital Site</th>
<th>Scanner</th>
<th>Make/Model</th>
<th>Slice</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CT1</td>
<td>Toshiba Aquilion</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td>Toshiba Aquilion</td>
<td>16</td>
</tr>
<tr>
<td>B</td>
<td>CT</td>
<td>Toshiba Aquilion</td>
<td>64</td>
</tr>
<tr>
<td>C</td>
<td>CT</td>
<td>Toshiba Aquilion</td>
<td>64</td>
</tr>
<tr>
<td>D</td>
<td>CT</td>
<td>Toshiba Aquilion</td>
<td>64</td>
</tr>
<tr>
<td>E</td>
<td>CT1</td>
<td>GE Discovery HD750 (dual kV) with ASIR</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td>GE Lightspeed</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>CT3</td>
<td>GE Lightspeed</td>
<td>64</td>
</tr>
<tr>
<td>F</td>
<td>CT</td>
<td>GE Lightspeed with (ASIR)</td>
<td>8</td>
</tr>
<tr>
<td>G</td>
<td>CT</td>
<td>GE Lightspeed</td>
<td>64</td>
</tr>
<tr>
<td>H</td>
<td>CT</td>
<td>Siemens Sensation</td>
<td>64</td>
</tr>
</tbody>
</table>

14th October 2010
Methodology – The Phantom

- Homogeneous, acrylic, elliptical, cone-shaped phantom.
- Same phantom used by ImPACT for their 2005 report (Thank you!).
- Designed to test each distinct AEC system (z-axis, rotational etc...)

 Phantom dimensions (30cm z-axis length).

---


14th October 2010
Methodology – Standard Settings

- Standardised test protocol for every CT scanner attempted for fair comparison (120kVp, 1 sec rot time, standard reconstruction parameters, 5mm slice recon, large FOV).
- However, slight variations unavoidable between models/manufacturers (below).

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Detector Rows</th>
<th>Collimation (mm)</th>
<th>Helical /Axial</th>
<th>Pitch</th>
<th>AEC system</th>
<th>Image quality settings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GE</strong></td>
<td>64</td>
<td>2x5</td>
<td>Axial</td>
<td>-</td>
<td>AutomA, SmartmA</td>
<td>NI 10, 10-750mA</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>8x1.25</td>
<td>Axial</td>
<td>-</td>
<td>AutomA, SmartmA</td>
<td>NI 10, 10-750mA</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8x1.25</td>
<td>Axial</td>
<td>-</td>
<td>Auto mA</td>
<td>NI 10, 10-440mA</td>
</tr>
<tr>
<td><strong>Siemens</strong></td>
<td>64</td>
<td>64x0.6</td>
<td>Helical</td>
<td>0.6</td>
<td>CARE Dose 4D</td>
<td>Average, 210 quality ref</td>
</tr>
<tr>
<td><strong>Toshiba</strong></td>
<td>64</td>
<td>16x0.5</td>
<td>Helical</td>
<td>0.938</td>
<td>SureExposure4D</td>
<td>SD 10, 10-380mA</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>16x0.5</td>
<td>Helical</td>
<td>0.938</td>
<td>SureExposure4D</td>
<td>SD 7.5, 80-410mA</td>
</tr>
</tbody>
</table>

14th October 2010
Methodology

- Scan projection radiographs (SPRs) acquired (AP and lateral) along entire phantom length.
- Scans of complete phantom length planned and performed from SPR images (based on previously described standard settings).
- Resulting sequence of images analysed in terms of two key parameters:
  1. Delivered mA for each slice (related to absorbed dose)
  2. Standard deviation of CT numbers in central ROI (measure of noise)

The effect of adjusting several parameters on applied x-ray tube current and image standard deviation (noise level) were recorded:
- kV
- Pitch
- Reconstruction kernel
- AEC image quality setting e.g. noise index

14th October 2010
Results

The following results are for 64-slice scanners only

14th October 2010
AEC system maintains image quality as the AP diameter is increased.

Image quality is improved when AutomA is combined with SmartmA.
AEC system maintains image quality as the AP diameter is increased.

Image quality is improved when z-axis AEC is combined with x, y-axis AEC.

14th October 2010
Results - Siemens

- Siemens z-axis and x, y-axis AEC system CareDose4D could not be operated independently.
- CareDose4D could either be selected with both AEC systems working together or not at all.
Varying image quality
Increasing image quality increases mA.

Image quality is maintained at the required level more accurately at lower NI values.
Results - Siemens

- Increasing the quality reference mAs increases the mA modulation.
- Image noise reduced for smaller AP diameters than larger ones. Therefore reducing the image noise for smaller patients and increasing it for larger ones (where it is more tolerable).

14th October 2010
AEC system behaves in a similar fashion to GE
Increasing image quality increases mA.
Image quality is maintained at the required level more accurately at lower SD values.
Increasing SD increases the AP diameter at which mA begins to be modulated.
Varying tube voltage
Changing kV does not alter image quality.

mA decreases when kV increases to maintain image quality.
Increasing kV increases the image quality, whilst mA remains constant at AP diameters greater than 130mm.
Results - Toshiba

- Changing kV does not alter image quality.
- mA decreases when kV increases to maintain image quality.
Varying reconstruction kernel
Changing the reconstruction algorithm changes the variation in CT number for each pixel making up the image to alter the appearance.

Reconstruction algorithm chosen did not alter the mA applied.
Behaves similar to GE.
Changing the reconstruction algorithm changes the variation in CT number for each pixel making up the image to alter the appearance.
Reconstruction algorithm chosen did not alter the mA applied.
Results - Toshiba

- Changing the reconstruction algorithm changes the variation in CT number for each pixel making up the image to alter the appearance.
- Reconstruction algorithm chosen alters the mA applied along the phantom length.
Varying pitch
Scan mode changed to helical with 40mm collimation to produce 5mm slices.

Lowering pitch causes mA along the phantom to be reduced in order to achieve the NI specified.

Reduced image noise between 100 and 250mm for increased pitch.

14th October 2010
Changing pitch has a similar effect on GE, Siemens and Toshiba 64 slice scanners.

Lowering pitch causes mA along the phantom to be reduced in order to achieve the image quality specified.
Results - Toshiba

- Changing pitch has a similar effect on GE, Siemens and Toshiba 64 slice scanners.
- Lowering pitch causes mA along the phantom to be reduced in order to achieve the image quality specified.

14th October 2010
Intra-manufacturer variation
Scanners with ASIR capabilities maintain image quality selected greater than the scanner without.

The same mA modulation is apparent for the three scanners.
Results - Toshiba

- Comparison of AEC system performance of four 64 slice Toshiba Aquilions.
- CT1 A and B behave differently to C and D with the same settings applied.
- C and D maintain greater image quality at increased AP diameters.

14th October 2010
Beware older scanners & software!
Performance of 16 slice Toshiba was found to be different in respect to the Toshiba 64 slice scanners.

- Older software version, different AEC system interface.
- mA modulation only occurs over a small AP diameter range (~5cm).
- Point at which mA modulation occurs increases with AP diameter.
Conclusion

- Scanners tested performed consistently with the findings described in the 2005 report by ImPACT\(^1\).
- Machines with apparently identical operation were found to have AEC systems which performed differently.
- Only through the individual testing of each scanner can the true behaviour of its AEC system be established.
- It is therefore essential that users operating each scanner fully understand not only how the relevant manufacturers AEC systems work in general but also how the specific scanner in their department operates.

Thank You

14th October 2010