Factors Affecting Image Quality & Radiation Dose in MDCT

2009.5.15

Ling GE CT Application specialist

Dose Information Display

Dose Information

Dose report
Note: The dose report page is automatically screen saved at the end of the exam.

Scan Range CTDI
CTDI (dose length product) CTDI phantom diameter

CT Dose Index
- average dose in a reference phantom

- 16 cm head & 32 cm body acrylic phantom (PMMA)
- Pencil type ion chamber
  - Sensitive length=100mm
- CTDI100
  - Dose at a point in standard phantoms
**CTDIw - CTDI weighted dose**

- Center (A) and peripheral (B) CTDI<sub>100</sub> measurements are combined
- CTDIw = 2/3 peripheral + 1/3 central CTDI<sub>100</sub> doses

**CTDIvol**

CTDIw = 2/3 peripheral + 1/3 central CTDI doses

- Axial: CTDIvol = Detection Width / Table Increment × CTDIw
- Helical: CTDIvol =Detection Width / Helical Pitch × CTDIw

**CTDIis**

- CTDI<sub>100</sub> - Dose at a point in standard phantoms
- CTDI<sub>w</sub> - Average dose in scan plan
- CTDI<sub>vol</sub> - Average dose over scanned volume

**DLP**

DLP = Exposure Length (not image range if helical) × CTDIvol

DLP = (mGy · cm) × CTDIvol (mGy)

- Helical Exposure Length (cm)
- Exposure time (s)
- Table speed (cm/s)
**Effective Dose**

The **EUR16262 Guidelines on Quality Criteria for CT** offers a table of factors that can be used to approximate effective dose.

- Uses dose units of mSv
- Is the only way to compare doses from different modalities

**How to measure effective dose?**

**EUR16262 Guidelines on Quality Criteria for CT – Table 2 body regions vs DLP multiplication factors to the rescue.**

\[ E = E_{DLP} \times DLP \]

An approximate effective dose value for estimating population dose effects

**Effective dose and comparisons for various procedures**

**What is the effective dose for a chest scan**

\[
E = E_{DLP} \times DLP
\]

3.62 mSv = 0.017 \times 213

0.017 is an example factor for chest from the **EUR16262 Guidelines**

**Table 1**

<table>
<thead>
<tr>
<th>CT Effective Dose Estimates Based on Anatomic Coverage Region</th>
<th>Assigned Effective Dose per CT Examination (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head, Brain</td>
<td>2</td>
</tr>
<tr>
<td>Cervical spine, neck</td>
<td>2</td>
</tr>
<tr>
<td>Clavicle, lung, pulmonary embolus, thoracic spine</td>
<td>8</td>
</tr>
<tr>
<td>Abdomen alone (no pelvis)</td>
<td>7.5</td>
</tr>
<tr>
<td>Pelvis alone (no abdomen)</td>
<td>7.5</td>
</tr>
<tr>
<td>Abdomen and pelvis, lumbosacral spine</td>
<td>15</td>
</tr>
<tr>
<td>Extremities</td>
<td>0</td>
</tr>
</tbody>
</table>

[Radiology: Volume 251, Number 1—April 2009 • radiology.rsna.org]

**Alara**

*As Low As Reasonably Achievable*

**Patient Dose**  
**Image Noise**

---

**Factors Affecting Image Noise**

- **X-ray**
  - kVp
  - mAs
  - Scan time
  - Helical pitch
  - Geometry
- **Filtration**
  - Bowtie
  - Filter quality
- **Patient**
  - Size
  - Shape
  - Centering
- **Anatomy**
- **Detection**
  - Slice width
- **Recon**
  - Algorithm
  - Helical Slice width
  - Helical weighting
  - Special filters (AAR)
- **Post Processing**
  - Image space filters
  - 3D, MPR, MIPs

---

**Image Noise**

**Factors Influencing Noise**

1. Tube current & scan time
   - mAs ↓, noise ↑
2. Tube voltage
   - KVP ↓, noise ↑

---

**Auto mA**

1. Optimizing radiation dose for different patient sizes and clinical indications.
2. Constant IQ and lower radiation dose.

---

Increasing the mA from 50 to 200 (a factor of 4) will decrease quantum noise by a factor of 2 (the square root of 4). 

You control the Image Quality & Patient Dose prospectively.
Based on the calculation of the oval ratio from projection views the mA prescribed for each gantry rotation is within the prescribed min/max mA range.

Auto mA

Auto mA Off/On

Click mA to open the mA Control

Max mA value for AutomA

Noise Index value for AutomA

Manual mA will use the same mA for the entire image group

Select [Manual mA] to set a fixed mA value for the scan

Enter the fixed mA value

Make sure the Manual mA value in every protocol is set to a reasonable value even if the protocol will use AutomA or SmartmA, just in case AutomA gets turned off.

Manual mA will use the same mA for the entire image group
**AutomA On**

- Select (AutomA) to turn it ON
- Set the Min and Max values over which AutomA is allowed to modulate.

**Min/Max mA**

<table>
<thead>
<tr>
<th>NR</th>
<th>Small FOV</th>
<th>Large FOV</th>
<th>Small FOV</th>
<th>Large FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>20</td>
<td>240</td>
<td>240</td>
<td>20</td>
</tr>
<tr>
<td>120</td>
<td>20</td>
<td>200</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>140</td>
<td>20</td>
<td>175</td>
<td>175</td>
<td>20</td>
</tr>
</tbody>
</table>

**AutomA**

- **Noise Index (NI)**
  - Default or baseline Noise Index for the given protocol. Any changes to Dose Steps, Slice Thickness or Noise index are referenced to this value.

**Reference Noise Index**

Default or baseline Noise Index for the given protocol. Any changes to Dose Steps, Slice Thickness or Noise index are referenced to this value. This value can only be prescribed while in protocol management.

**Dose Steps**

Adjusts NI by steps of 5%. Dose steps can be increased or decreased. Plus values decrease image noise thus increasing required mA. Minus values increase image NI, thus decreasing required mA.

A Dose Step value of 0 indicates that the prescribed NI is equal to the Reference NI for the protocol.
The Dose Step arrows increase or decrease the relative dose by 1 relative dose unit.

1 relative dose unit is:
- 5% noise index change
- 10% mA change

**Example #1**
- Dose step decreased by 1
- mA decreased by 10%
- Noise index increased by 5%

**Example #2**
- Dose step increased by 2
- mA increased by 20%
- Noise index decreased by 10%

**AutomA**

Reset

Resets the Reference Noise Index to the GE Target Noise Index Default for the anatomical area and slice thickness chosen in the protocol.

**AutomA**

The Noise Index value is the only way to reproduce consistent results.

- NI ↑, mA ↓
- NI ↓, mA ↑
AutomA

The mA Table reports what the mA will be for each scan rotation, based on the factors you have set on the AutomA Control.

These factors are applied to the patient data gathered for the last scout taken (typically AP). Use the same kV for scanning as used on this Scout.

Always check the mA Table before proceeding on to Confirm the Rx.

AutomA adjust in the Z axis only.

SmartmA Off/On

Select [SmartmA] to turn it ON.

AutomA must be selected first, then SmartmA is available.

SmartmA

SmartmA Modulation
- Modulates 4 times per rotation
- Modulation ramp is 100 ms

Incident X-ray flux decreased vs angle depending on patient asymmetry
**SmartmA**

**Dose with AutomA**

<table>
<thead>
<tr>
<th>Dose Information</th>
<th>Images</th>
<th>CTDHVL</th>
<th>mSv/yr</th>
<th>DLPR mGy*cm</th>
<th>DLPR Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SmartPrep</td>
<td>43.85</td>
<td>43.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected series DLPR</td>
<td>278.80</td>
<td>mGy*cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulated scan DLPR</td>
<td>1094.40</td>
<td>mGy*cm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dose with SmartmA**

<table>
<thead>
<tr>
<th>Dose Information</th>
<th>Images</th>
<th>CTDHVL</th>
<th>mSv/yr</th>
<th>DLPR mGy*cm</th>
<th>DLPR Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SmartPrep</td>
<td>43.85</td>
<td>43.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected series DLPR</td>
<td>242.65</td>
<td>mGy*cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulated scan DLPR</td>
<td>1094.40</td>
<td>mGy*cm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*A tilde – following the NI# indicates that SmartmA was also ON.*

**3D Dose Modulation**

- **Constant dose**
- **X, Y – changing mA with a slice**
- **Smart mA**
- **Z – changing mA along patient**
- **Auto mA**
- **3D mA modulation**

**Scout mA**

Scout mA value has no effect on determining scan mA.

<table>
<thead>
<tr>
<th>Scout = 10 mA</th>
<th>Scout = 80 mA</th>
<th>Scout = 200 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scout mA</td>
<td>mA</td>
<td>mA</td>
</tr>
<tr>
<td>10 mA</td>
<td>507</td>
<td>507</td>
</tr>
<tr>
<td>20 mA</td>
<td>497</td>
<td>497</td>
</tr>
<tr>
<td>30 mA</td>
<td>487</td>
<td>487</td>
</tr>
<tr>
<td>40 mA</td>
<td>477</td>
<td>477</td>
</tr>
<tr>
<td>50 mA</td>
<td>467</td>
<td>467</td>
</tr>
<tr>
<td>60 mA</td>
<td>457</td>
<td>457</td>
</tr>
<tr>
<td>70 mA</td>
<td>447</td>
<td>447</td>
</tr>
<tr>
<td>80 mA</td>
<td>437</td>
<td>437</td>
</tr>
</tbody>
</table>

**From Single Scout View**
**Scout kV**

140 Scout / 120 Axial

Both at 140

kV between Scout and Axial series is very important!

**Auto mA Tips**

1. AutomA will use the last scout taken to compute the required mA. The lowest dose will be computed from an AP scout. You may use PA or Lateral, but they will raise the computed dose.

2. Scout view must include the entire region being scanned with Auto mA.

3. Auto and smart mA will be disable if the patient orientation does not match the orientation of the scout.

4. Avoid p’t movement after scout

5. Appropriate centering of p’t in gantry isocenter, particularly in table high. Noise can increase with off centering

**ECG mA Modulation - in cardiac scan**

- Modulated dose based on ECG signal

• Modulated dose based on ECG signal

- Systole

- Diastole

**Cardiac Helical is a high dose procedure**

Helical Overbeaming Incorrect heart phase

Detector X –ray off

Detector X –ray on

Z location

Time
ECG mA modulation can help

- Detector: X-ray off
- Time
- Z location
- Max mA
- Min mA
- % Ma Modulation

ECG modulation

- User selectable parameters
  - Min and Max mA settings
  - Adjustable phase %
- Data can be used for functional analysis
- Up to 50% dose reduction

Collimation - Dose efficiency

- Z-axis dose efficiency is the % of the x-ray beam over the detector relative to the width of the beam.

ECG modulation

- mA Control
- Full mA range: <65 bpm, 70-80%
  >65 bpm, 40-80%

<table>
<thead>
<tr>
<th>Patient Size</th>
<th>Minimum mA Value</th>
<th>Maximum mA Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>180 mA</td>
<td>450 mA</td>
</tr>
<tr>
<td>Medium</td>
<td>220 mA</td>
<td>550 mA</td>
</tr>
<tr>
<td>Large</td>
<td>300 mA</td>
<td>750 mA</td>
</tr>
</tbody>
</table>

- 10 mm: 20%  83%  93%
- 20 mm: 10%  91%  94%
- 40 mm: 5%   95%  98%
Factors Affecting Image Noise

- X-ray:
  - kVp
  - mAs
  - Scan time
  - Helical pitch
  - Geometry

- Filtration:
  - Bowtie
  - Beam quality

- Patient:
  - Size
  - Shape
  - Centering
  - Anatomy

- Detection:
  - Slice width

- Recon:
  - Algorithm
  - Helical Slice width
  - Helical weighting
  - Special filters (AAR)

- Post Processing:
  - Image space filters
    - 3D, MPR, MIPs

Factors Affecting Image Noise

- X-ray:
  - kVp
  - mAs
  - Scan time
  - Helical pitch
  - Geometry

- Filtration:
  - Bowtie
  - Beam quality

- Patient:
  - Size
  - Shape
  - Centering
  - Anatomy

- Detection:
  - Slice width

- Recon:
  - Algorithm
  - Helical Slice width
  - Helical weighting
  - Special filters (AAR)

- Post Processing:
  - Image space filters
    - 3D, MPR, MIPs

Bowtie filter (SFOV)

Bowtie Filters are intended to:
1. Maintain a uniform image
2. Minimize the surface dose (Patient skin dose)
3. Reduce x-ray scatter

Patient Centering

- Elevated 4 cm
- Elevated 6 cm

It's as if we threw away half the available tube power
Patient Centering

Why the large noise increase?

- Excessive dose
- Centering error
- Dose too low

Thickest part of patient intersects thickest part of bowtie filter

Factors Affecting Image Noise

- X-ray kVp, mAs
- Scan time, Helical pitch, Geometry
- Filtration, Bowtie, Beam quality
- Patient Size, Shape, Centering, Anatomy
- Detection Slice width
- Reconstruction Algorithm, Helical Slice width, Helical weighting, Special filters (AAR)
- Post Processing Image space filters, 3D, MPR, MIPs

Factors Affecting Image Noise

- Image Noise
- DAS
- Recon-struction
- Slice width

Slice width

- 5mm
- 1.25mm

Slice width ↓, noise ↑

% Effective mA reduction contours with the LightSpeed body bowtie filter

Patient mis-centering contributes significantly to low signal streaking

High noise streaks due to mis-centering

Patient 6 cm too low

Increased dose to breast

% Effective mA reduction contours

Patient 6 cm too low

0%

50%

90%
Factors Affecting Image Noise

Recon algorithm

A mathematical calculation, which controls low contrast detectability and spatial resolution in the reconstructed image.

- **Soft**: Used to visualize soft tissue structures that are similar in density. Lowest spatial resolution. Best low contrast detectability.
- **Standard**: The most commonly used algorithm for most soft tissue studies. It provides a nice mixture of soft tissue resolution and spatial resolution.
- **Lung**: Used to visualize interstitial lung markings.
- **Detail**: Used to highlight soft tissue surrounded by high density objects such as the spinal canal surrounded by spine.

Recon algorithm

- **Bone**: Used to enhance high density objects such as bone for fractures or to provide high resolution images in the chest to best visualize lung tissue.
- **Edge**: Used to enhance the edges of high density objects in small intricate areas, such as mastoids or IAC’s.
- **Bone Plus**: Another step up in resolution to use with thin slice thickness (0.625).

Window vs. Filter vs. Algorithm

CT Display
Full and Plus Recon Options

The system provides the ability to manage dose, slice profile, and helical artifact through the Full and Plus recon modes.

Full mode provides a thinner slice profile but requires 10-15% more mA than Plus mode with equal image noise.

Plus mode has up to 20% wider slice profile than Full, but requires 15-20% less mA with equal noise.

Note: Only available on 8, 16, 32 and 64 slice systems.

Full and Plus Recon Options

Both Full and Plus modes can be used prospectively and retrospectively including Prospective Multiple reconstructions (PMR).

Data acquired in Plus mode can be retrospectively reconstructed in Full mode, or data acquired in Full mode can be reconstructed in Plus mode.

Image Noise - Filters

IQ Enhance (where applicable)

If Helical scan type is selected, IQ Enhance will be available if the slice thickness is 0.625mm or 1.25mm and the interval for these slices thicknesses is equal to the slice thickness (0.625 or 1.25) or one half the slice thickness (0.312 or 0.625).

Neuro 3D Filters (where applicable)

Noise reduction filters for thin sliced acquisitions for applications where data will be manipulated in 3D modes such as reformat or maximum intensity projections for neuro applications. The filters are Low/N1, Med/N2, and High/N3.

N1 Filter will allow for an estimated 15% reduction in dose.

N2 Filter will allow for an estimated 15-30% reduction in dose.

N3 Filter will allow for an estimated reduction exceeding 30%
**Image Noise - Filters**

Cardiac Noise Reduction Filters (where applicable)

Cardiac noise reducing and edge preserving filters C1, C2, or C3 are available for Cardiac helical exams. These filters allow you to reduce the dose up to 30% on top of ECG modulation dose reduction while preserving the same image quality.

**Factors Affecting Image Noise**

- **X-ray**
  - kVp
  - mA
  - Scan time
  - Helical pitch
  - Geometry

- **Filtration**
  - Bowtie filter
  - Beam quality

- **Patient**
  - Size
  - Shape
  - Centering
  - Anatomy

- **Detection**
  - Slice width
  - Helical weighting
  - Special filters (AAR)

- **Recon**
  - Algorithm
  - Helical Slice width
  - Helical weighting
  - Special filters (AAR)

**Postprocessing Image Filters**

- **S1, S2, S3**
  - These smooth enhancements are used for filming soft tissue windows when there is a need to decrease the appearance of noise in an image.
  - These enhancements may be useful when there are bone artifact streaks on an image such as in the hip and shoulder areas.
  - Enhances low contrast areas.

  **Note:** Filter does not transfer to PACs.

Thank you for your attention!