



AAPM Computed Tomography Automatic Exposure Control Education Slides

Many of the terms used in these slides can be found in the CT
Terminology Lexicon

<http://www.aapm.org/pubs/CTProtocols/documents/CTTerminologyLexicon.pdf>

Last Updated 2021-12-06



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Motivation

- These slides are provided to aid in understanding the factors that affect performance of Automatic Exposure Control, specifically image quality and radiation dose, in CT studies



Outline

- Effect of CT localizer on AEC
- Image quality reference parameter for AEC
- Effect of patient size on AEC
- Effect of scanned anatomy
- Effect of first or expected reconstruction settings
- Advanced AEC features



Effect of CT Localizer

- The CT localizer(s) provide the initial data to inform the behavior of the AEC
- The apparent size of the patient on the localizer(s) or the measured attenuation are used to set the initial dose level for the exam
- The localizer(s) may also be used to adjust the longitudinal or angular tube current modulation
- The use of multiple localizers and the order of their acquisition may affect the behavior of the system's AEC



Effect of CT Localizer – Philips

- If only one localizer is acquired, the choice of the localizer (AP vs. Lateral vs. PA) does not impact AEC calculations
- If two localizers are acquired, the order of the localizer (AP + LAT vs LAT + AP) does not impact AEC calculations
 - PA (AP not possible) for Philips
- The scanning parameters (e.g. tube voltage, mA) of the localizer do not impact AEC calculations
 - This is assuming that the localizer is not under-dosed and there is sufficient penetration.



Effect of CT Localizer – vendor recommendations – Philips

- For head/neck exams it is recommended to use:
 - one localizer
 - lateral localizer, if only one localizer is used
 - PA first, if two localizers are used
 - Both Fixed tube voltage for localizer and matching tube voltage of localizer to the following CT acquisition(s) is OK to use.
 - a minimum of 120/120 kV and 30/30 mA on an average size adult patient for AP/PA and lateral, respectively
- For chest/abdomen/pelvis exams it is recommended to use:
 - one localizer
 - PA localizer, if only one localizer is used
 - PA first, if two localizers are used
 - Both Fixed tube voltage for localizer and matching tube voltage of localizer to the following CT acquisition(s) is OK to use.
 - a minimum of 120/120 kV and 30/30 mA on an average size adult patient for AP/PA and lateral, respectively



Effect of CT Localizer – Philips

- Mis-centering of the patient does not impact AEC calculations
- If a patient appears mis-centered in the localizer, the operator can judge the centering of the patient from the console and can compensate for the mis-centering without entering the scanner room
- Once the patient mis-centering has been corrected, it is not recommended that a new localizer be acquired for accurate AEC calculations



Effect of CT Localizer – Philips

- If the prescribed CT scan range exceeds the range of the acquired localizer, the AEC algorithm:
 - Linearly increases from the technique at the closest z location to the maximum. If 30% of the prescribed scan length is outside of the localizer boundary then AEC will become inactive.



Image quality reference parameter for AEC

- The image quality reference parameter for AEC is generally a measure of image quality in the reconstructed images
- The image quality reference parameter for AEC has a unique relationship with both tube output and patient size
- Specifically, the Image quality reference parameter is used together with the patient attenuation profile (as estimated by the CT localizer) to determine the tube output for a particular exam
- The operation of the AEC may be independent of the reconstruction parameters, or related to them



Image quality reference parameter(s) for AEC – Philips

- The primary image quality reference parameter for AEC for this manufacturer is called: [Dose Right Index (DRI)]
- If a reference patient size is used by the AEC, it is different for adults and pediatric protocols.
 - However, this is only for usability. The performance of AEC is independent on the chosen reference size]



Effect of image quality reference parameter for AEC – Philips

- The tube output (i.e., effective mAs) has the following relationship with the image quality reference parameter for AEC (all other factors being equal):
 - Linear increase
- Please provide a curve or schematic showing the tube output vs image quality reference parameter profile for one or more patient attenuation values
 - Each step is a 12% increase/decrease



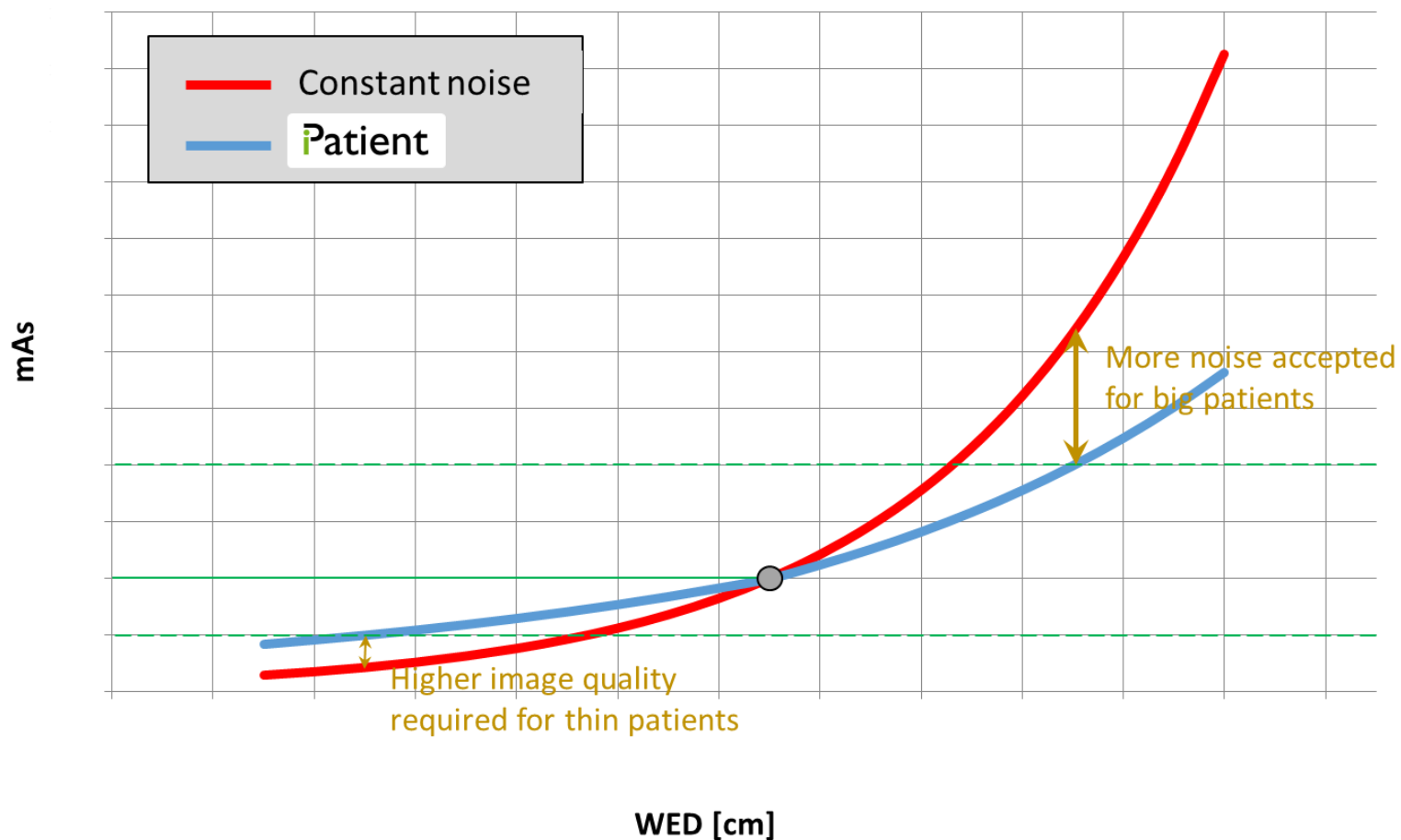
Effect of patient size – Philips

- The tube output (i.e., effective mAs) has the following relationship with the size of the patient (all other factors being equal):
 - A less than exponential increase, to provide higher image noise for larger patients, and lower image noise for smaller patients



Effect of Patient Size – Philips

Automatic mAs adjustment to account for patient size





Effect of scanned anatomy – Philips

- The tube output (i.e., effective mAs) is affected by the organ or anatomy being scanned (all other factors being equal)
 - This is user selectable. User can optionally choose to boost liver or brain mAs. Amount of boost is configurable
- If the organ or anatomy being scanned affects the tube output (other than intrinsic differences in attenuation), please describe which parameter in the CT protocol affects this particular behavior.
 - Liver Boost, Brain Boost. Configured by DRI change in those areas



Effect of first or expected reconstruction settings – Philips

- The tube output (i.e., effective mAs) is independent of the first/expected reconstruction for that protocol (all other factors being equal)

- If the first or expected reconstruction affects the tube output, please describe which parameters in the CT protocol affect this particular behavior, and how they influence the tube output.
 - N/A



Advanced AEC Features Outline

- AEC in cardiac exams
- Unusual attenuation profiles
 - Head/Neck exams (strategy to handle abrupt change of attenuation profile)
 - Extremity exams
 - Neonates and very small children
 - Metal/Foreign objects within Scan FOV
 - Obese patients
- Automatic tube voltage selection
- Organ based tube current modulation



AEC in cardiac exams – Philips

- ECG-based tube current modulation is available
- When ECG-based tube current modulation is activated:
 - there is not simultaneous Longitudinal (z) tube current modulation
 - there is not simultaneous Angular (x-y) tube current modulation
 - Please specify if different between scanning mode (e.g. prospective vs retrospective gating)
 - Retrospective mode only



AEC in cardiac exams – Philips

- In Prospective Triggering Mode with table movement,
 - there is not option for tube current modulation at selected cardiac phase range.
 - there is Adaptive triggering to handle irregular heart beat.



AEC in cardiac exams - Setup of prospective triggering mode – Philips

A desired phase of 78% is selected (selected at lower right and listed on left panel). A phase tolerance value of 0% is selected. That means x-rays are only on for the 78% phase. Phase tolerance can be increased up to 5% in order to turn the x-rays on for additional time (e.g., from 73-82% of the cardiac cycle).

The screenshot displays the Philips CT console interface for setting up a Step&Shoot, Ax exam. The left panel shows a list of protocols with 'Step&Shoot, Ax' selected, and 'Scan Parameters' for 120 kV, 155 mAs, 78% phase, and 0% tolerance. The right panel shows detailed parameters for '4 Step&Shoot, Ax', including rotation time (0.27), 2 cycles, and bolus tracking trigger.

Scan Parameters (Left Panel):

- kV: 120
- mAs: (mA) 155 (731)
- Est. Scan Time: 4-8
- Phase: 78 %
- Expected HR: NaN BPM
- CTDIvol: 12.4-37.2mGy
- DLP: 160-399mGy*cm
- Phantom: 32cm

Step&Shoot, Ax Parameters (Right Panel):

- Rotation Time: 0.27
- No. of Cycles: 2
- Estimated Scan Time: 4-8
- Auto Voice: S. Inspiration, Breathe
- Breathing Lights:
- Edit before final Recon:
- Full coverage, longer cycle time:
- Injection: Injection Parameters...
- Contrast:
- Trigger: Bolus Tracking
- Post Threshold Delay: 7
- Length (Z): 144.5 mm
- Direction: In Out
- Dose Notification: Dose Notification Value CTDIvol: 50 mGy, Dose Notification Value DLP: None mGy*cm
- ECG Gating: Phase: 78 %, Phase Tolerance: 0 %, Handle irregularities on-line



AEC in cardiac exams – Philips

- In Retrospective Gating Mode with table movement,
 - there is option for tube current modulation at selected cardiac phase range
 - If the answer to above question is Yes, for the cardiac phase range where the user intends to reduce dose, the reduction of tube current is fixed at 80%



AEC in cardiac exams – Setup of retrospective gating – Philips

Cardiac DoseRight is checked on (upper right). Cardiac DoseRight is the tool that lowers the mAs by 80% outside of the desired cardiac phase for ECG-gated helical scanning.

The screenshot displays the Philips CT console interface. On the left, a sidebar shows a list of scan protocols: 1. Surview, Dual; 2. Locator, locator; 3. Bolus Tracker, tracker; 4. Cardiac, Helical (4.1 75%, Coronary, 0.9x0.45). Below this is the 'Scan Parameters' section with the following values: kV: 120; mAs: (mA) 800 (471); Scan Time: 5.3 sec; Expected HR: NaN BPM. Technical data shown includes CTDIvol: 51.4mGy, DLP: 968.3mGy*cm, and Phantom: 32cm. A 'Show All...' button is present. The main window is titled 'Coronary CTA - Show All' and shows 'All Parameters' for '4 Cardiac, Helical'. The 'Dose Management' tab is active, with the 'Cardiac DoseRight' checkbox checked and circled in red. Other settings include: Label: (empty); Collimation: Auto (128x0.625); Sampled Collimation: 256; Pitch: 0.160; Rotation Time: 0.27; Automatic Scan Time: unchecked; Scan Time: 5.3 sec; Auto Voice: checked; Breathing Lights: checked; Edit before final Recon: checked; Injection: unchecked; Contrast: checked; Trigger: Bolus Tracking; Post Threshold Delay: 5. Dose Notification values are set to 150 mGy for CTDIvol and None for DLP. A 'Save As...' button is at the bottom left and a 'Close' button is at the bottom right.



AEC in cardiac exams – Setup of retrospective gating – Philips

A desired phase of 75% is selected (selected at lower right and listed on left panel). It's designated as a coronary phase which means it gets the full dose; it is the only phase of the cardiac cycle that receives full dose while all other phases get dose reduced by 80%.

The screenshot displays the Philips CT console interface. On the left, the 'Scan Parameters' panel shows a list of scan phases: 1. Surview, Dual; 2. Locator, locator; 3. Bolus Tracker, tracker; 4. Cardiac, Helical; and 5. 4.1 75%, Coronary, 0.9x0.45. The 'Phase' dropdown is set to 75% and is circled in red. Below this, the 'Scan Parameters' section shows kV: 120, mAs: (mA) 800 (471), Scan Time: 5.3 sec, Expected HR: NaN BPM, CTDIvol: 51.4mGy, DLP: 968.3mGy*cm, and Phantom: 32cm. A 'Show All...' button is visible below the parameters. The main window, titled 'Coronary CTA - Show All', shows the 'All Parameters' tab. The 'Overview' section displays '4.1 75%, Coronary, 0.9x0.45' with a 'Procedure' dropdown, 'Result Direction: Head to feet', and 'Render Mode: Average'. The 'Distribution' section includes 'Auto Storage' (Local), 'Auto Film' (Auto Film Parameters), and 'Auto Launch' (None). The 'Geometry' section shows 'Field Of View: 220 mm', 'Length (Z): 140.40 mm', 'Center X: 0 mm', and 'Center Y: 0 mm'. The 'ECG Gating' section shows 'Phase: 75 %' and 'Cardiac Functionality: Coronary' (selected). At the bottom, there are 'Save As...' and 'Close' buttons.



AEC in cardiac exams – Setup of retrospective gating – Philips

The pop-up window shows the selection of two “coronary” phases: 40 and 70. This means the tube current stays high for both of these phases ramping down to the lower mAs value everywhere else. The user can select up to 6 coronary phases.

The screenshot displays the Philips CT console interface. On the left, the 'Scan Parameters' section shows: kV: 120, mAs: (mA) 800 (471), Scan Time: 5.3 sec, Phase: 75 %, Expected HR: NaN BPM, CTDIvol: 51.4mGy, DLP: 968.3mGy*cm, Phantom: 32cm. A 'Show All...' button is visible below. The main window shows 'Coronary CTA - Show All' with 'All Parameters' selected. The 'Overview' tab is active, showing '4.1 75%, Coronary, 0.9x0.45'. A 'Distribution' section is highlighted. A 'Geometry' section shows Field Of View: 220, Length (Z): 140.40, Center X: 0, Center Y: 0. A 'Pop-up window' titled 'Edit Phases' is open, showing a list of 'Coronaries' and 'Functional' phases. The 'Coronaries' tab is selected, and the list shows: Cardiac Phase #1: 75 %, Cardiac Phase #2: 40 %, Cardiac Phase #3: %, Cardiac Phase #4: %, Cardiac Phase #5: %. A 'Delete All' button is at the bottom of the pop-up. The 'Apply' and 'Cancel' buttons are also visible.



Unusual attenuation profiles – Philips

- For head/neck exams, there is no specific scan direction recommended for best AEC dose modulation
- To achieve ideal image quality/dose performance, there is not dedicated AEC parameter settings for head/neck exams.



Unusual attenuation profiles – Philips

- The following are clinical scenarios where achieving desired image quality/dose performance can be challenging with the use of AEC. If applicable to your system, please provide comments/cautions accordingly:
 - Scanning neonates and very small children
 - There are Metal/Foreign objects within scan FOV
 - Extremity exams:
 - Lower extremity
 - Upper extremity with arm(s) raised up above the shoulder
 - Upper extremity with arms(s) kept down aside the torso

No specific recommendation.



Unusual attenuation profiles – Philips

- For scans where the tube power limitations are reached using AEC, automatic adjustment of the scanning parameters is available
 - Automatic Scan Time (i.e. Rotation Time, Pitch)



Unusual attenuation profiles – Philips

The screenshot displays the Philips CT scanner software interface. On the left, a tree view shows the scan protocol: 1 Surview, Frontal; 2 Abdomen/Pelvis, Helical (highlighted); 2.1 3x3. Below this, 'Age Group' is set to 'Adult' and 'Patient Size' to '50-90kg'. The main area is titled 'All Parameters' and shows settings for '2 Abdomen/Pelvis, Helical'. A red oval highlights the 'Automatic Scan Time' checkbox, which is checked. Other parameters include: Scan Type: Abdomen/Pelvis; Collimation: Auto (128x0.625); Sampled Collimation: 256; Pitch: 0.914; Rotation Time: 0.4; Scan Time: 3 sec; Resolution: Standard; Auto Voice: S. Inspiration, Breathe; Breathing Lights: checked; Edit before final Recon: checked; DoseRight Index: 26 (Reduce Dose); Z-Modulation: checked; 3D Modulation: checked; kV: 120; mAs for Average Adult: 251; Absolute Min mAs: None; Absolute Max mAs: None; Liver Area DoseRight Index: +3; Ref. Size: 29 cm; CTDIVol: 19.6 mGy; DLP: 980.5 mGy*cm; Accumulated DLP: 980.5 mGy*cm; Phantom: CTDIVol Body Phantom 32cm; Injection: unchecked; Contrast: unchecked; Trigger: Manual; Dose Notification Value CTDIVol: 50 mGy; Dose Notification Value DLP: None mGy. Buttons for 'Save', 'Save As', and 'Cancel' are at the bottom left.

Parameter	Value
Scan Type	Abdomen/Pelvis
Collimation	Auto (128x0.625)
Sampled Collimation	256
Pitch	0.914
Rotation Time	0.4
Automatic Scan Time	Checked
Scan Time	3 sec
Resolution	Standard
Auto Voice	S. Inspiration, Breathe
Breathing Lights	Checked
Edit before final Recon	Checked
DoseRight Index	26
Z-Modulation	Checked
3D Modulation	Checked
kV	120
mAs for Average Adult	251
Absolute Min mAs	None
Absolute Max mAs	None
Liver Area DoseRight Index	+3
Ref. Size	29 cm
CTDIVol	19.6 mGy
DLP	980.5 mGy*cm
Accumulated DLP	980.5 mGy*cm
Phantom	CTDIVol Body Phantom 32cm
Injection	Unchecked
Contrast	Unchecked
Trigger	Manual
Dose Notification Value CTDIVol	50 mGy
Dose Notification Value DLP	None mGy



Automatic Tube voltage selection – Philips

- Automatic tube voltage selection based on the CT localizer scan(s) is not available



Organ based tube current modulation – Philips

- Organ-based tube current modulation is available
 - All scanners with iPatient and Incisive CT
- The change in tube output (i.e. effective mAs) for projections over the organ of interest is 12% per 1 DRI cumulative (*positive for increase*)



Organ based tube current modulation – Philips

- If organ-based modulation is activated for a CT scan, the total tube output (mAs) is higher than or the same as without organ-based modulation with other scanning conditions kept the same.
- When organ-based modulation is enabled, there is not restriction on other scanning techniques (i.e. rotation time, pitch).
- Organ-based modulation is available for the following exam types:
 - Body and Brain



Organ based tube current modulation – Philips

The screenshot displays the Philips CT scanner software interface for a 'Carotid CTA' scan. The left sidebar shows a sequence of steps: 1. Surview, Dual; 2. Locator, locator; 3. Bolus Tracker, tracker; 4. CTA Carotid, Helical (highlighted). Below the sidebar are 'Age Group: Adult' and 'Patient Size: 50-90kg'. The main panel is titled '4 CTA Carotid, Helical' and contains various parameters:

- Scan Type: CTA Carotid
- Collimation: Auto (128x0.625)
- Sampled Collimation: 256
- Pitch: 0.758
- Rotation Time: 0.33
- Automatic Scan Time:
- Scan Time: 2.1 sec
- Resolution: Standard
- Auto Voice:
- Breathing Lights:
- Edit before final Recon:
- Injection: (Injection Parameters... button)
- Contrast:
- Trigger: Bolus Tracking
- DoseRight Index: Reduce Dose 26
- Z-Modulation:
- 3D Modulation:
- kV: 120
- mAs for Average Adult: 251
- Absolute Min mAs: None
- Absolute Max mAs: None
- Brain Area DoseRight Index: +4 (highlighted with a red circle)
- Ref. Size: 29 cm
- CTDIvol: 22.6 mGy
- DLP: 775.4 mGy*cm
- Accumulated DLP: 862.2 mGy*cm
- Phantom: CTDIVol Body Phantom 32cm
- Dose Notification Value CTDIVol: 80 mGy
- Dose Notification Value DLP: None mGy

Buttons at the bottom include 'Save', 'Save As', and 'Cancel'.



Acknowledgements

- AAPM Alliance for Quality CT Members

Izabella Barreto	Christopher Favazza	Ilana Neuberger
Kirsten Lee Boedeker	Andrea Ferrero	Joseph Och
Laurel Burk	Dustin Gress	Karen Reed
Adam Chandler	Jeffrey Guild	Franco Rupcich
Theresa Csepegi	Ninad Gujar	Liz Russell
Dan Demaio	Ahmed Halaweish	Pooyan Sahbaee Bagherzadeh
Amar Dhanantwari	Sandra Halliburton	Andrew Scott
Cristina Dodge	Kalpana Kanal	Mark Supanich
Xinhui Duan	Baojun Li	Timothy Szczykutowicz
Sue Edyvean	Sarah McKenney	Jia Wang

- A special thank you to Dr. Jia Wang and Dr. Andrea Ferrero for their considerable efforts in developing these slides.