



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>

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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



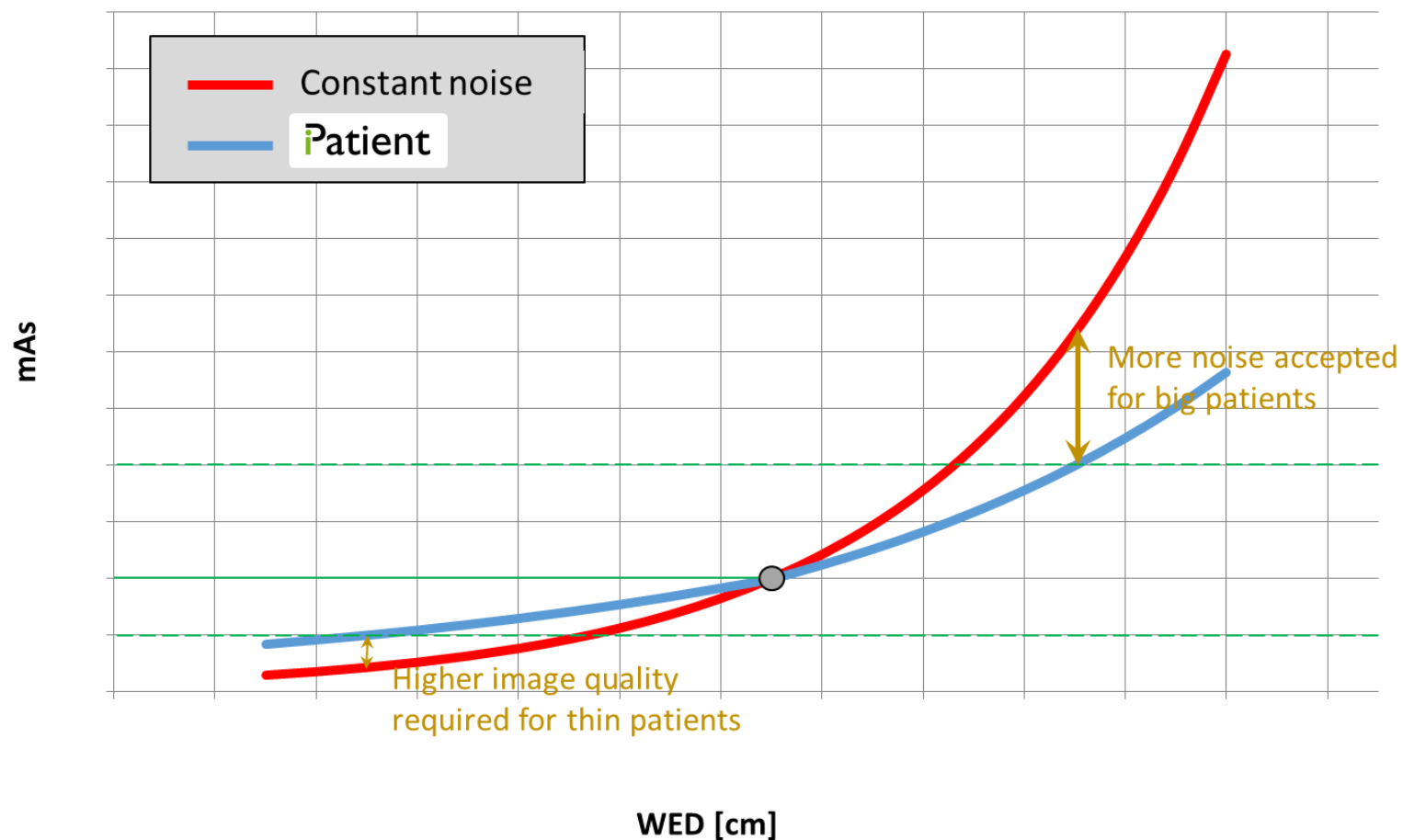
Effect of patient size – Philips

- 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).

Switch Screen 0000015

1 Surview, Dual
2 Locator, locator
3 Bolus Tracker, tracker
4 Step&Shoot, Ax
4.1 78%, None, 0.8x0.4

Scan Parameters

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

Show All...

Go

Step&Shoot - Show All

Overview All Parameters

4 Step&Shoot, Ax

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

CTDIvol: 12.4-37.2 mGy DLP: 160-399 mGy*cm
Accumulated CTDI: 37.2 mGy Accumulated DLP: 482.7 mGy*cm
Phantom: CTDIvol Body Phantom 32cm

Injection

☐ Injection Injection Parameters...
☒ Contrast
Trigger: Bolus Tracking
Post Threshold Delay: 7

Geometry

Length (Z): 144.5 mm
Direction: ☐ In ☒ Out

ECG Gating

Phase: 78 %
Phase Tolerance: 0 %
☒ Handle irregularities on-line

Dose Notification

Dose Notification Value CTDIvol: 50 mGy
Dose Notification Value DLP: None mGy*cm

Save As... Close



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 for a Cardiac CTA exam. The left sidebar shows a list of exam protocols, with 'Cardiac, Helical' selected. 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. The main window is titled 'Coronary CTA - Show All' and has tabs for 'Overview' and 'All Parameters'. The 'All Parameters' tab is active, showing settings for '4 Cardiac, Helical'. The 'General' section includes fields for Label, Collimation (Auto), 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), and Edit before final Recon (checked). The 'Dose Management' section has a red circle around the 'Cardiac DoseRight' checkbox, which is checked. Other settings in this section include kV (120), mAs for Average Adult (mA) 800 (471), CTDIvol: 51.4mGy, DLP: 968.3mGy*cm, Accumulated CTDE: 51.4mGy, Accumulated DLP: 1036.5mGy*cm, and Phantom: CTDIvol Body Phantom 32cm. The 'Injection' section shows Injection (unchecked), Contrast (checked), Trigger (Bolus Tracking), and Post Threshold Delay (5). The 'Dose Notification' section shows Dose Notification Value CTDIvol: 150 mGy and Dose Notification Value DLP: None mGy*cm. At the bottom, there are 'Save As...' and 'Close' buttons.

Switch Screen

1 Surview, Dual

2 Locator, locator

3 Bolus Tracker, tracker

4 Cardiac, Helical

4.1 75%, Coronary, 0.9x0.45

Scan Parameters

kV: 120

mAs: (mA) 800 (471)

Scan Time: 5.3 sec

Expected HR: NaN BPM

CTDIvol: 51.4mGy

DLP: 968.3mGy*cm

Phantom: 32cm

Show All...

Go

Coronary CTA - Show All

Overview All Parameters

4 Cardiac, Helical

General

Label:

Collimation: Auto (128x0.625)

Sampled Collimation: 256

Pitch: 0.160

Rotation Time: 0.27

Automatic Scan Time

Scan Time: 5.3 sec

Auto Voice

Breathing Lights

Edit before final Recon

Dose Management

Cardiac DoseRight

kV: 120

mAs for Average Adult: (mA) 800 (471)

CTDIvol: 51.4mGy

DLP: 968.3mGy*cm

Accumulated CTDE: 51.4mGy

Accumulated DLP: 1036.5mGy*cm

Phantom: CTDIvol Body Phantom 32cm

Injection

Injection

Injection Parameters...

Contrast

Trigger: Bolus Tracking

Post Threshold Delay: 5

Dose Notification

Dose Notification Value CTDIvol: 150 mGy

Dose Notification Value DLP: None mGy*cm

Save As...

Close



AEC in cardiac exams – Setup of retrospective gating – Philips

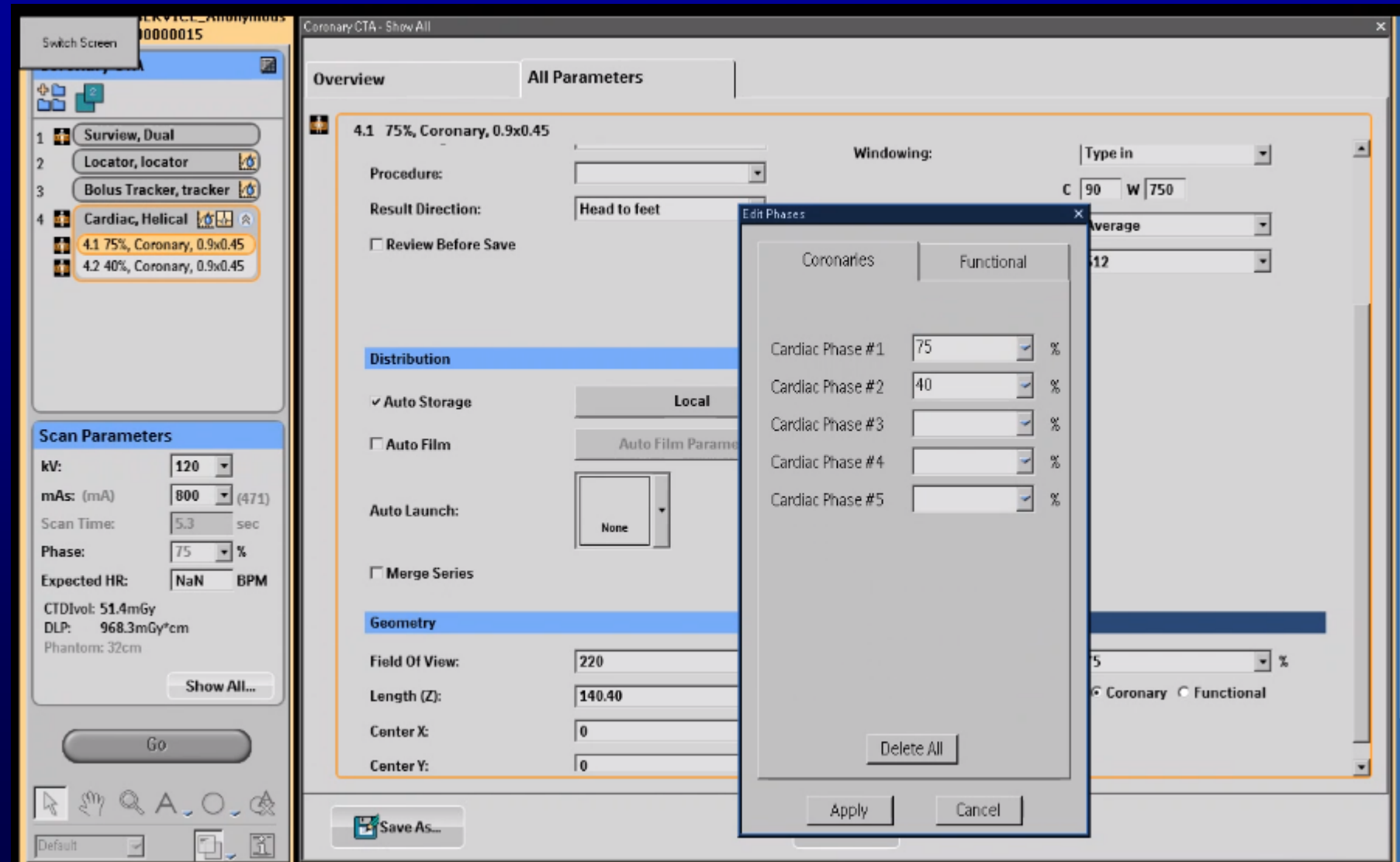
A desired phase of 75% is selected (selected at lower right and listed on left panel). It's designated as a coronary phase which means it gets the full dose; it is the only phase of the cardiac cycle that receives full dose while all other phases get dose reduced by 80%.

The screenshot displays the Philips CT console interface for setting up a cardiac exam. On the left, a list of scan phases is shown, with '4.1 75%, Coronary, 0.9x0.45' selected and highlighted in orange. Below this, the 'Scan Parameters' section shows 'kV: 120', 'mAs: (mA) 800 (471)', 'Scan Time: 5.3 sec', and 'Phase: 75 %' (circled in red). The 'Expected HR: NaN BPM' is also displayed. On the right, the 'Coronary CTA - Show All' window is open, showing the 'All Parameters' tab. The 'Overview' section includes '4.1 75%, Coronary, 0.9x0.45' as the procedure, 'Head to feet' as the result direction, and 'Average' as the render mode. The 'Distribution' section shows 'Auto Storage' checked and 'Local' as the storage location. 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.





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

Abdomen

1 Surview, Frontal

2 Abdomen/Pelvis, He... 2.1 3x3

Age Group: Adult

Patient Size: 50-90kg

Save Save As Cancel

Overview All Parameters

2 Abdomen/Pelvis, Helical

Scan Type: Abdomen/Pelvis

Collimation: Auto (128x0.625)

Sampled Collimation: 256

Pitch: 0.914

Rotation Time: 0.4

☒ Automatic Scan Time

Scan Time: 3 sec

Resolution: Standard

☒ Auto Voice

☒ Breathing Lights

☒ Edit before final Recon

S. Inspiration, Breathe

Injection

☐ Injection

☐ Contrast

Trigger: Manual

DoseRight Index: Reduce Dose 26

☒ Z-Modulation

☒ 3D Modulation

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

Dose Notification

Dose Notification Value CTDIvol: 50 mGy

Dose Notification Value DLP: None mGy

Injection Parameters...

Injection Parameters...



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

Carotid CTA

1 **Surview, Dual**

2 **Locator, locator**

3 **Bolus Tracker, tracker**

4 **CTA Carotid, Helical**

4.1 2x2

4.2 0.9x0.45

Age Group: **Adult**

Patient Size: **50-90kg**

Save **Save As**

Cancel

Overview **All Parameters**

4 CTA Carotid, Helical

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 **Injection Parameters...**

☒ 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

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

Dose Notification Value CTDIVol: **80** mGy

Dose Notification Value DLP: **None** mGy



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