



*AAPM Computed Tomography Radiation  
Dose Education Slides  
GE Healthcare Version*

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

[http://www.aapm.org/pubs/CTProtocols/docu  
ments/CTTerminologyLexicon.pdf](http://www.aapm.org/pubs/CTProtocols/documents/CTTerminologyLexicon.pdf)

Last updated: 18 November 2013



## *Disclaimer*

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## Disclaimer

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- Screen captures are **examples** of a common (or latest) software version only and all software versions are not represented
- The information contained herein is current as of the date shown on the title slide
- The master version of these slides is located at:
  - <http://www.aapm.org/pubs/CTProtocols/documents/EducationSlides.pptx>
- Modification of the content of these slides is **not allowed**.



## *Vendor Specific Slide Details*

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- The presence of a vendor name in the footer of the slide indicates that the slide is vendor specific slide
- White text is used throughout to indicate vendor specific language
- An example of a vendor specific slide follows





## *Generic Parameter/Topic Name*

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Vendor Specific Name

Vendor screen  
capture of how the  
acquisition  
parameter is set  
or how  
information on the  
topic is displayed

Text describing acquisition  
parameter or topic



## Motivation

- These slides are provided to aid in understanding the factors that affect radiation dose in CT studies
- Image patients **wisely** and **gently**
  - A CT study should use as little radiation as possible, while still meeting the image quality needs of the exam
  - A CT study that is non-diagnostic because the radiation dose is too low may require rescanning the patient – increasing the total patient dose



[imagegently.org](http://imagegently.org)

[imagewisely.org](http://imagewisely.org)





## Outline

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- What is Dose?
- Acquisition Parameter Settings
- Dose Modulation and Reduction
- Dose Display



## What Is Dose?

- Volume Computed Tomography Dose Index ( $CTDI_{vol}$ ) is a standardized parameter to measure **Scanner Radiation Output**
  - $CTDI_{vol}$  is NOT patient dose
  - $CTDI_{vol}$  is reported in units of mGy for either a 16-cm (for head exams) or 32-cm (for body exams) diameter acrylic phantom
  - For the same technique settings, the  $CTDI_{vol}$  reported for the 16-cm phantom is about twice that of the 32-cm phantom
  - The reported  $CTDI_{vol}$  is based on measurements made by the manufacturer in a factory setting
- In these slides, the term "patient dose" is used to describe the absorbed dose to a patient, while the generic term "dose" refers to  $CTDI_{vol}$

1. Bauhs, J. A., Vrieze, T. J., Primak, A. N., Bruesewitz, M. R., & McCollough, C. H. (2008). CT Dosimetry: Comparison of Measurement Techniques and Devices1. *Radiographics*, 28(1), 245-253. doi:10.1148/rg.281075024
2. McCollough, C. H., Primak, A. N., Braun, N., Kofler, J., Yu, L., & Christner, J. (2009). Strategies for reducing radiation dose in CT. *Radiologic clinics of North America*, 47(1), 27-40.
3. International Electrotechnical Commission. *Medical Electrical Equipment. Part 2–44: Particular requirements for the safety of x-ray equipment for computed tomography*. 2.1. International Electrotechnical Commission (IEC) Central Office; Geneva, Switzerland: 2002. IEC publication No. 60601–2–44.



## *How is $CTDI_{vol}$ related to patient dose?*

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- $CTDI_{vol}$  is not patient dose
- The relationship between the two depends on many factors, including patient size and composition
- [AAPM Report 204](#) introduces a parameter known as the Size Specific Dose Estimate (SSDE) to allow estimation of patient dose based on  $CTDI_{vol}$  and patient size
- For the same  $CTDI_{vol}$ , a smaller patient will tend to have a higher patient dose than a larger patient

What is Dose?

[http://www.aapm.org/pubs/reports/RPT\\_204.pdf](http://www.aapm.org/pubs/reports/RPT_204.pdf)



## How is $CTDI_{vol}$ related to patient dose?

120 kVp at 200 mAs



32 cm  
Phantom

$CTDI_{vol} = 20 \text{ mGy}$

120 kVp at 200 mAs



32 cm  
Phantom

$CTDI_{vol} = 20 \text{ mGy}$

**Both patients scanned with the same  $CTDI_{vol}$**   
**Patient dose will be higher for the smaller patient**

What is Dose?



## How is $CTDI_{vol}$ related to patient dose?

120 kVp at 100 mAs



32 cm  
Phantom

$CTDI_{vol} = 10$  mGy

120 kVp at 200 mAs



32 cm  
Phantom

$CTDI_{vol} = 20$  mGy

**Smaller patient scanned with a lower  $CTDI_{vol}$   
Patient doses will be approximately equal**

What is Dose?



## Size Specific Dose Estimate (SSDE)

- AAPM report 204 describes a method to calculate SSDE using  $CTDI_{vol}$
- Conversion factors based on patient size (e.g., AP or lateral width, effective diameter) are provided to **estimate** patient dose for a patient of that size
- However, SSDE is still not the exact patient dose, as factors such as scan length and patient composition may differ from the assumptions used to calculate SSDE
- SSDE is not dose to any specific organ, but rather the mean dose in the center of the scanned volume

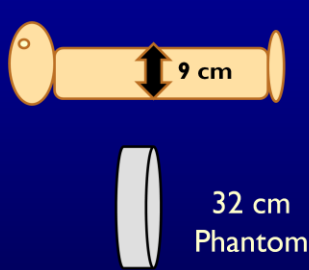
What is Dose?





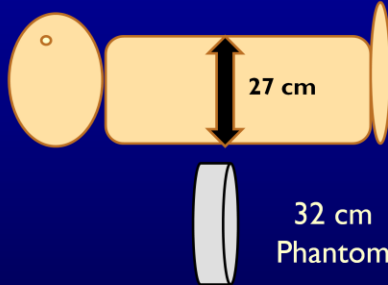
## How is $CTDI_{vol}$ related to patient dose?

120 kVp at 100 mAs



$CTDI_{vol} = 10 \text{ mGy}$   
 $SSDE = 13.2 \text{ mGy}$

120 kVp at 200 mAs



$CTDI_{vol} = 20 \text{ mGy}$   
 $SSDE = 13.2 \text{ mGy}$

**Patients have equivalent SSDE**

What is Dose?



## Why Use $CTDI_{vol}$ ?

- $CTDI_{vol}$  provides information about the amount of radiation used to perform the study
- $CTDI_{vol}$  is a useful index to track across patients and protocols for quality assurance purposes
- $CTDI_{vol}$  can be used as a metric to compare protocols across different practices and scanners when related variables, such as resultant image quality, are also taken in account
- The ACR Dose Index Registry (DIR) allows comparison across institutions of  $CTDI_{vol}$  for similar exam types (e.g., routine head exam)

What is Dose?

1. McCollough, C. H., Leng, S., Yu, L., Cody, D. D., Boone, J. M., & McNitt-Gray, M. F. (2011). CT Dose Index and Patient Dose: They are Not the Same Thing, EDITORIAL, *Radiology* 259(2), 311-316.



## *Dose Length Product*

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- The Dose Length Product (DLP) is also calculated by the scanner
- DLP is the product of the length of the irradiated scan volume and the average  $CTDI_{vol}$  over that distance
- DLP has units of  $mGy \cdot cm$

What is Dose?



## Useful Concepts/Terms

- The relationships between acquisition parameters and  $CTDI_{vol}$  described in the following slides assume all other parameters are held constant
- The relationship between a parameter and  $CTDI_{vol}$  is often described as **proportional** in some way
  - The symbol  $\propto$  is used to indicate “proportional to”
- Directly proportional means that a change in the parameter results in the same change in  $CTDI_{vol}$ 
  - Example: Doubling the rotation time from 0.5 to 1.0 seconds will double the  $CTDI_{vol}$
- Inversely proportional means that a change in a parameter has the opposite effect on  $CTDI_{vol}$ 
  - Example: Doubling the pitch from 1 to 2 will reduce the  $CTDI_{vol}$  by half



## *Acquisition Parameter Settings*

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- Acquisition Parameters define the technique that will be used and how the scan will proceed
- Acquisition Parameters are set in the user interface where scans are prescribed
- Changing a single Acquisition Parameter while holding everything else constant will typically affect the  $CTDI_{vol}$  for that scan
- The following slides describe what that affect is for each parameter



## Scan Mode

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- CT Scanners offer a variety of **Scan Modes** which describe how the table moves during an exam
- **Scan Modes** include
  - Axial
  - Helical or Spiral
  - Dynamic

**The Acquisition Parameters that affect CTDIvol may change amongst different Scan Modes**

Acquisition Parameter Settings



## Dynamic Scan Mode Notes

- In the Dynamic Scan Mode multiple acquisitions covering the same body region are acquired. Examples of these study types include:
  - Perfusion Studies
  - Bolus Tracking Studies
  - Test Bolus Studies
- Dynamic Scans often have large  $CTDI_{vol}$  values because the scanner reports the sum of the  $CTDI_{vol}$  values from each rotation
- The reported  $CTDI_{vol}$  is NOT skin dose or organ dose

Acquisition Parameter Settings

1. Bauhs, J. A., Vrieze, T. J., Primak, A. N., Bruesewitz, M. R., & McCollough, C. H. (2008). CT Dosimetry : Comparison of Measurement Techniques and Devices. *Radiographics*, 28(1), 245-254.
2. Zhang, D., Cagnon, C. H., Villablanca, J. P., McCollough, C. H., Cody, D. D., Stevens, D. M., Zankl, M., et al. (2012). Peak Skin and Eye Lens Radiation Dose From Brain Perfusion CT Based on Monte Carlo Simulation. *American Journal of Roentgenology*, 198(2), 412-417.



## GE Healthcare: Scan Mode

### Axial Scan Type

Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (mm)
Split						
1-10	Axial Full 1.0 s	\$0.000	\$0.000	10	5.0 1i	0.000

Zero Interval, 1i mode and same location for Start/End, sets the scanner to acquire the specified Number of Images at the same location to track a contrast bolus for a Test Bolus acquisition.

Acquisition Parameter Settings

In Axial mode, zero interval provides ability to acquire No. of Images at the same table location to provide data with time sensitive information.





# GE Healthcare: Scan Mode

## Cine Scan Type

Protocol: 1.28 CT Perfusion 350-370 Strcm Series: 3

Anatomical Reference: OM

Patient Orientation: Head First

Patient Position: Supine

Series Description: Perfusion 370 -40ml/4ccsec

Dose Information:

Images	CTDIvol mGy	DLP mGy-cm	Dose Eff. %	Phantom cm
1-712	530.37	2121.48	92.60	Head 16

Projected series DLP: 3894.04 mGy-cm  
Accumulated exam DLP: 0.00 mGy-cm

Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (mm)	Gantry Tilt	SFOV	kV	mA	Total Exposure Time	Prep Group (s)	ISI (s)	Breath Hold (s)	Breathe Time (s)	Voice Lights Timer	Cine Duration (s)
1-712	One Full 1.8 s	39,000	325,000	712	5.0 81 0.30 s	0.000	38.0	Head	80	180	45.01	5.0	1.0	■	■	■	45.0

In Cine Mode, Cine Duration defines how long the x-ray is on for a given location. If the interval is 0, the table does not move and the full duration is at the prescribed location, as in CT Perfusion imaging.

Acquisition Parameter Settings

In Cine mode, Cine Durations defines the period of time that x-ray is on for a given location. The interval can be zero such as in CT Perfusion image or be equal to the detector coverage such as in retrospective respiratory gating acquisitions.



## *Table Feed/Increment*

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- Is the movement of the table through the bore of the scanner over a full 360 degree rotation
- Units: millimeters/rotation or millimeters/second
- The parameter is known both as **Table Feed** (helical/spiral acquisition) & **Table Increment** (axial acquisition)

**Table Feed may affect  $CTDI_{vol}$  through its inclusion in Pitch (discussed later)**

Acquisition Parameter Settings

AAPM Working Group on Standardization of CT Nomenclature and Protocols

## GE Healthcare: Table Feed/Increment

### Helical – mm/rot

In Helical, table feed (speed) is expressed in mm per rotation based on the detector coverage and pitch selected. (Note that both mm/rot and mm/s are provided).

Acquisition Parameter Settings

In Helical Table Feed (Speed) is expressed in mm per rotation based on the Detector Coverage and Pitch selected and the Thickness Speed screen.

AAPM Working Group on Standardization of CT Nomenclature and Protocols

# GE Healthcare: Table Feed/Increment

## Axial and Cine – interval

Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval	Gantry
1-12	Axial Full 1.0 s	\$0.000	\$35.000	12	5.0 41	20.000	30.0
13-28	Axial Full 1.0 s	\$60.000	\$135.000	16	5.0 41	20.000	30.0

In Axial and Cine, Increment (interval) is expressed in mm based on the detector coverage selected in Interval.

Acquisition Parameter Settings

In Axial and Cine, Increment (interval) is expressed in mm based on the Detector Coverage selected in the Thickness Speed screen. In Axial and Cine, the Increment (Interval) is equal to Detector Coverage.



## Detector Configuration

- Is the combination of the number of data channels and the width of the detector associated with each data channel
- The **Detector Configuration** determines the Beam Width or Beam Collimation ( $nT$ ), which is the number of channels ( $n$ ) times the detector width associated with each data channel ( $T$ )
- For a selected detector width per data channel, a smaller total Beam Collimation usually has a higher  $CTDI_{vol}$  than a larger Beam Collimation
  - Example: On a 16 slice scanner with a detector width per channel of 1.25 mm, a collimation of  $4 \times 1.25\text{mm}$  is generally less dose efficient than a collimation of  $16 \times 1.25\text{mm}$

**Users should monitor  $CTDI_{vol}$  values when changing detector configuration**

Acquisition Parameter Settings



# GE Healthcare: Detector Configuration

## Axial, Cine, Helical, Cardiac Scan Type - Detector Coverage

The image displays four screenshots of the GE Healthcare CT acquisition parameter settings interface, arranged in a 2x2 grid. Each screenshot shows the 'Detector Coverage' configuration for a specific scan type: Axial, Helical, Cine, and Cardiac. The settings are as follows:

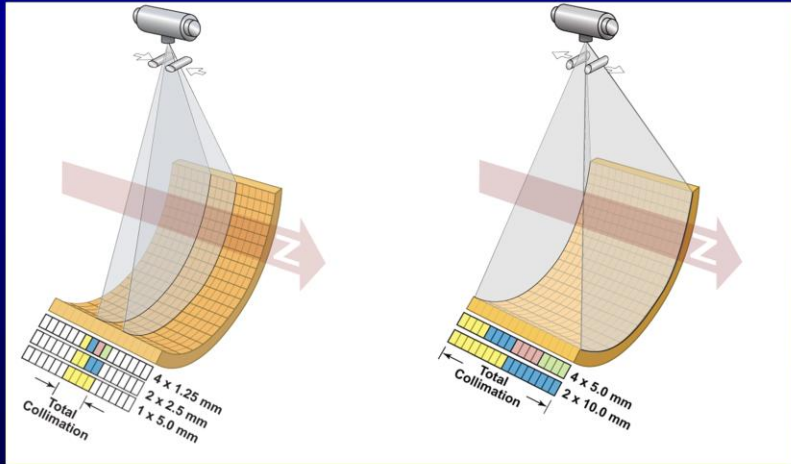
- Axial:** Detector Coverage (mm) [1.25, 2.5, 5.0], Axial Thickness (mm) [10.0, 20.0, 40.0], Coverage Time: 5.0 s, Rotation Time (s) [0.80, 1.25, 2.0, 3.0, 4.0], Pitch & Speed (mm/s) [0.825, 1.25, 2.5, 5.0].
- Helical:** Detector Coverage (mm) [20.0, 40.0], Axial Thickness (mm) [0.625, 1.25, 2.5], Coverage Time: 4.0 s, Rotation Time (s) [0.30, 0.37, 0.4, 0.50, 0.60, 0.80, 0.9, 1.0, 1.20, 1.50, 1.8], Pitch & Speed (mm/s) [0.825, 1.25, 2.5, 5.0].
- Cine:** Detector Coverage (mm) [1.25, 2.5, 5.0], Axial Thickness (mm) [10.0, 20.0, 40.0], Coverage Time: 2.0 s, Rotation Time (s) [0.30, 0.37, 0.4, 0.50, 0.60, 0.80, 0.9, 1.0, 1.20, 1.50, 1.8], Pitch & Speed (mm/s) [0.825, 1.25, 2.5, 5.0].
- Cardiac:** Detector Coverage (mm) [40.0], Axial Thickness (mm) [0.625, 1.25, 2.5], Coverage Time: 4.0 s, Rotation Time (s) [0.30, 0.37, 0.4, 0.50, 0.60, 0.80, 0.9, 1.0, 1.20, 1.50, 1.8], Pitch & Speed (mm/s) [0.825, 1.25, 2.5, 5.0].

Detector Configuration for 64 slice systems always acquires using 0.625 mm elements. Detector Coverage defines how much of the configuration is used for the acquisition.

Acquisition Parameter Settings



## Detector Configuration



Acquisition Parameter Settings



## Pitch

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- Is the Table Feed per gantry rotation divided by the beam width/collimation
- **Pitch** is the ratio of two distances and therefore has no units
- Users should monitor other parameters when changing **Pitch**. The scanner may or may not automatically compensate for changes in **Pitch** (for example, by changing the tube current) to maintain the planned  $CTDI_{vol}$ .

**$CTDI_{vol} \propto 1/Pitch$ :**

**Hitachi, Toshiba (no AEC)**

**$CTDI_{vol}$  independent of Pitch:**

**GE, Siemens, Philips, Neusoft, Toshiba (AEC)**

Acquisition Parameter Settings





## Pitch

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- $CTDI_{vol}$  may not change in the expected manner if the scanner automatically adjust other parameters when the pitch is changed
- The relationships between  $CTDI_{vol}$  and pitch for the different vendors are described below
  - $CTDI_{vol}$  inversely proportional to change in pitch: Hitachi, NeuroLogica
  - $CTDI_{vol}$  constant when pitch is changed due to changes to other parameters: GE, Neusoft, Philips and Siemens
  - The relationship between  $CTDI_{vol}$  and pitch depends on scan mode or Software version: Toshiba

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# GE Healthcare: Pitch

## Pitch selection is based on Detector Coverage

Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (mm)	Gantry Tilt
1-81	Helical Full 0.5 s	30.000	1400.000	81	5.0 55.00 1.375:1	5.000	30.0

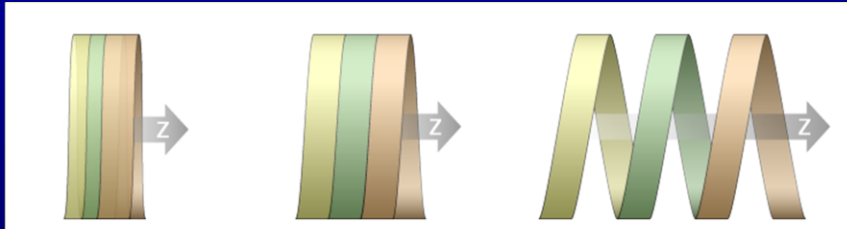
Pitch & Speed (mm/rot)	
0.516:1 20.62	0.894:1 38.37
1.375:1 55.00	

Acquisition Parameter Settings

Pitch selection is based on Detector Coverage.



## Pitch



**Pitch < 1**  
Beam Width has some overlap at each view angle from rotation to rotation

**Pitch = 1**  
No overlap of Beam Width at each view angle and no view angles not covered at certain table positions

**Pitch > 1**  
Some view angles are not covered by the beam width at certain table positions

Acquisition Parameter Settings



## *Exposure Time per Rotation*

- Is the length of time, in seconds, that the X-ray beam is “on” during a gantry rotation
  - It takes into account the gantry rotation time and angular acquisition range
- Units: seconds
- Users should monitor other parameters when changing **Exposure Time per Rotation**. The scanner may or may not automatically compensate for changes in **Exposure Time per Rotation**(for example, by changing the tube current)

**$CTDI_{vol} \propto$  Exposure Time per Rotation**

**Hitachi, NeuroLogica, Toshiba (no AEC)**

**$CTDI_{vol}$  independent of Exposure Time per Rotation:**

**GE, Siemens, Philips, Neusoft, Toshiba (AEC)**

Acquisition Parameter Settings



## *Exposure Time per Rotation*

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- $CTDI_{vol}$  may not change in the expected manner if the scanner automatically adjust other parameters when the exposure time per rotation is changed
- The relationships between  $CTDI_{vol}$  and exposure time per rotation for the different vendors are described below
  - $CTDI_{vol}$  proportional to change in parameter: Hitachi and NeuroLogica
  - $CTDI_{vol}$  constant when the parameter is changed due to changes to other parameters: GE, Neusoft, Philips and Siemens
  - The relationship between  $CTDI_{vol}$  and the parameter depends on scan mode or Software version: Toshiba



# GE Healthcare: Exposure Time per Rotation

Rotation time is changed and Manual mA value is not changed, CTDIvol is changed.

Protocol: 6.2 Chest Abd Pelvis 0.40.5 s 5m Series: 2

**Dose Information**

Images	CTDIvol mGy	DLP mGy-cm	Dose Est. %	Phantom cm
1-61	6.68	243.82	92.60	Body 32
62-122	10.03	365.47	92.60	Body 32

Projected series DLP: 608.29 mGy-cm  
Accumulated exam DLP: 0.00 mGy-cm

Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (mm)	Gantry Tilt	SFOV	kV	mA	Total Exposure Time	Prep Group (s)	ASD (s)	Breath Hold (s)	Breath Time (s)	Voice Lights Timer	Close Duration (s)
1-61	Helical Full 0.4 s	30.000	1300.000	61	5.0 50.00 1.375:1	5.000	30.0	Large Body	120	300	2.65	30.0	1.3	N	N	2 T	2.0
62-122	Helical Full 0.4 s	30.000	1300.000	61	5.0 50.00 1.375:1	5.000	30.0	Large Body	120	300	3.98	35.0	1.3	N	N	2 T	2.0

Acquisition Parameter Settings

If the Rotation Time is changed and the Manual mA value is not changed, the CTDIvol will be changed.



## *Tube Current*

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- Determines the number of electrons accelerated across the x-ray tube per unit time
- Units: milliAmperes (mA)
- $CTDI_{vol}$  is directly proportional to **Tube Current**

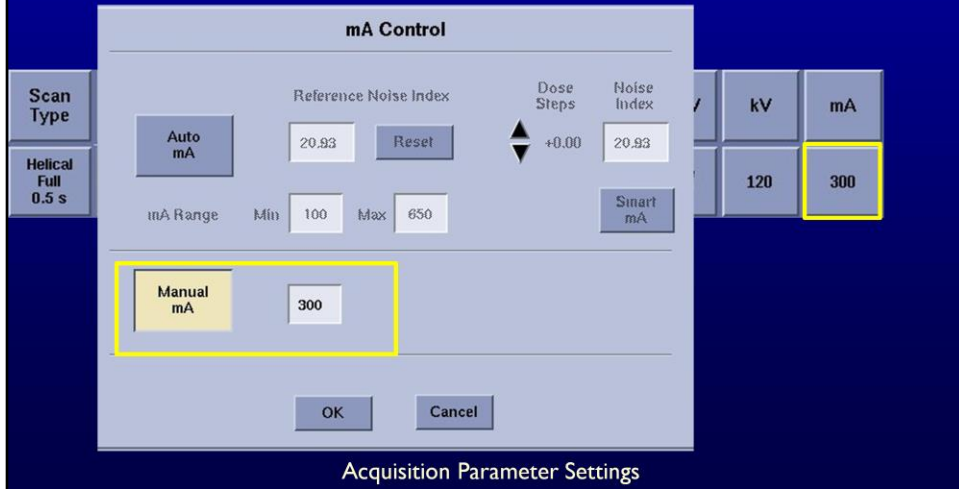
$$CTDI_{vol} \propto \text{Tube Current}$$

Acquisition Parameter Settings



## GE Healthcare: Tube Current

### Manual mA Control



Manual mA Control allows entry of explicit mA value with in the valid mA range of 10 to 835mA depending on X-Ray tube and generator type.





## Tube Potential

- Is the electrical potential applied across the x-ray tube to accelerate electrons toward the target material
- Units: kiloVolts (kV or kVp)
- $\text{CTDI}_{\text{vol}}$  is **approximately** proportional to the square of the percentage change in **Tube Potential**

$$\text{CTDI}_{\text{vol}} \propto \left( \frac{kV_{\text{new}}}{kV_{\text{old}}} \right)^n$$

$n \approx 2 \text{ to } 3$

Acquisition Parameter Settings

**AAPM Working Group on Standardization of CT Nomenclature and Protocols**

## GE Healthcare: Tube Potential

### Manual kV Control pop-up

The screenshot displays a software interface for manual kV control. At the top, a blue header contains the AAPM logo and the text 'AAPM Working Group on Standardization of CT Nomenclature and Protocols'. Below this, the title 'GE Healthcare: Tube Potential' is shown in orange, followed by 'Manual kV Control pop-up' in white. The main interface is a dark blue panel with a light blue grid of acquisition parameters. A pop-up window titled 'Select the desired kV.' is open, showing four buttons for 80, 100, 120, and 140 kV, with the 120 kV button highlighted in yellow. A 'Cancel' button is also present. The acquisition parameter table below has the 'kV' column highlighted in yellow, showing a value of 120. The table includes columns for Images, Scan Type, Start Location, End Location, No. of Images, Thick Speed, Interval (mm), Gantry Tilt, SFOV, kV, mA, and Total Exposure Time.

Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (mm)	Gantry Tilt	SFOV	kV	mA	Total Exposure Time
1-12	Axial Full 1.0 s	\$0.000	\$55.000	12	5.0 4i	20.000	\$0.0	Head	120	300	3.00

Acquisition Parameter Settings

Using Manual kV control, kV is selected from pop-up menu for selection of 80, 100, 120, 140 kV.



## *Tube Current Time Product*

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- Is the product of Tube Current and the Exposure Time per Rotation
- Units: milliAmpere-seconds (mAs)
- $CTDI_{vol}$  is directly proportional to Tube Current Time Product

$$CTDI_{vol} \propto \text{Tube Current Time Product}$$

Acquisition Parameter Settings



## GE Healthcare: Tube Current Time Product

mAs is manual calculation of mA x rotation time

Group 1 – 200mA x 1s = 200mAs at 140kV

Group 2 – 320mA x 1s = 320mAs at 120kV

Images		Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (mm)	Gantry Tilt	SFOV	kV	mA	Total Exposure Time	Prep Group (s)	ISD (s)	Breath Hold (s)	Breathe Time (s)	Voice Lights Timer	Cine Duration (s)
1-12	Actual Full 1.0 s	\$0.000	\$55.000	12	5.0 41	20.000	\$0.0	Head	140	200	3.00	0.0	1.3	N	N	N	N	2.0
13-28	Actual Full 1.0 s	\$00.000	\$135.000	16	5.0 41	20.000	\$0.0	Head	120	320	4.00	1.0	1.3	N	N	N	N	2.0

Acquisition Parameter Settings



## *Field Of Measurement*

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- Is the diameter of the primary beam in the axial plane at the gantry iso-center
- Units: millimeters (mm)
- $CTDI_{vol}$  may decrease with a decrease in the Field of Measurement
  - The relationship is vendor specific

**Users should monitor the  $CTDI_{vol}$  values when changing the Field of Measurement**

Acquisition Parameter Settings



## GE Healthcare: Field of Measurement

Scan-Field-of-View is used to define this parameter on GE CT systems. SFOV is selected by a body region button and maps to (25 or 32) or 50 cm.

Select the desired SFOV.

Ped Head		Ped Body		Small Head		Head		Small Body		Medium Body		Large Body		Cancel	
Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (min)	Gantry Tilt	SFOV	kV	mA	Total Exposure Time				
Split															
1-61	Helical Full 0.5 s	\$0.000	1300.000	61	5.0 55.00 1.375:1	5.000	\$0.0	Large Body	120	300	3.32				

Acquisition Parameter Settings

Scan-Field-of-View is used to define this parameter. Scan-Field-of-View is 32 or 50cm depending on mode selected. Some model maybe 25 or 50cm.



## *Beam Shaping Filter*

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- Is the scanner component that modifies the energy spectrum and spatial distribution of the primary beam
- **Beam Shaping** may include a bow tie filter and/or flat filters
- $CTDI_{vol}$  is affected by a change in **Beam Shaping Filters**
  - The relationship is vendor and filter specific

**Users should monitor  $CTDI_{vol}$  values when changing the Beam Shaping Filter**

Acquisition Parameter Settings



## GE Healthcare: *Beam Shaping Filter*

Scan Field of View – SFOV selects the bowtie filter.  
 GE systems have 2 or 3 bowtie filters.

Select the desired SFOV.

Ped Head	Ped Body	Small Head	Head	Small Body	Medium Body	Large Body	Cancel
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Images	Scan Type	Start Location	End Location	No. of Images	Thick Speed	Interval (min)	Gantry Tilt	SFOV	kV	mA	Total Exposure Time
1-61	Helical Full 0.5 s	S0.000	I300.000	61	5.0 55.00 1.375:1	5.000	S0.0	Large Body	120	300	3.32

Acquisition Parameter Settings

SFOV selects the bowtie or which there can be 3 depending on system – small, medium large.

Small – Ped Head, Ped Body, Small Head, Small Body, Cardiac Small

Medium – Head, Medium Body, Cardiac Medium

Large – Large Body, Cardiac Large

Some systems may only have 2 bowtie.

Small – Ped Head, Ped Body, Head, Small Body, Cardiac Small

Large – Large Body, Cardiac Large





## Acquisition Parameter Settings Summary

Parameter	Relationship to $CTDI_{vol}$
Scan Mode	Changes in the Scan Mode may affect $CTDI_{vol}$
Table Feed/Increment	Table Feed affects $CTDI_{vol}$ through its inclusion in Pitch
Detector Configuration	Decreasing the Beam Collimation typically, but not always, increases the $CTDI_{vol}$
Pitch	$CTDI_{vol}$ relationship to pitch is vendor dependent
Exposure Time Per Rotation	$CTDI_{vol}$ relationship to exposure time per rotation is vendor dependent
Tube Current	$CTDI_{vol} \propto$ Tube Current
Tube Potential	$CTDI_{vol} \propto (kVp_1/kVp_2)^n$ $n \sim 2$ to $3$
Tube Current Time Product	$CTDI_{vol} \propto$ Tube Current Time Product
Effective Tube Current Time Product	$CTDI_{vol} \propto$ Effective Tube Current Time Product
Field of Measurement	Changes in the Field of Measurement may affect $CTDI_{vol}$
Beam Shaping Filter	Changes in the Beam Shaping Filter may affect $CTDI_{vol}$



## *Dose Modulation and Reduction*

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- Many CT scanners automatically adjust the technique parameters (and as a result the  $CTDI_{vol}$ ) to achieve a desired level of image quality and/or to reduce dose
- Dose Modulation and Reduction techniques vary by scanner manufacturer, model and software version



## Automatic Exposure Control (AEC)

- Automatically adapts the Tube Current or Tube Potential according to patient attenuation to achieve a specified image quality
  - Automatic adjustment of Tube Current may not occur when Tube Potential is changed
  - **Centering the patient in the gantry is VITAL for most AEC systems**
- AEC aims to deliver a specified image quality across a range of patient sizes. It tends to increase  $CTDI_{vol}$  for large patients and decrease it for small patients relative to a reference patient size

**The use of Automatic Exposure Control may decrease or increase  $CTDI_{vol}$  depending on the patient size and body area imaged and image quality requested**

Dose Modulation and Reduction



## GE Healthcare: Automatic Exposure Control (AEC)

AutomA/Smart mA are AEC modes for non-gated modes.

**mA Control**

Reference Noise Index: 14.68 (Reset) +0.00 (Steps) 14.68 (Noise Index)

Auto mA

mA Range: Min 50 Max 700

Smart mA

Manual mA: 350

OK Cancel

SFOV	kV	mA	DFOV (cm)	R/L Center (mm)	A/P Center (mm)	Recon Type	Matrix Size	Recon Option	Auto Apps
Large Body	120	700 14.68	36.0	80.0	80.0	Std	512	Plus 400/50 SSS0	Off

Auto Scan Accept Series Auto Transfer R1 R2 R3 R4 R5 R6 R7 R8 R9 R10

Dose Modulation and Reduction



## GE Healthcare: Automatic Exposure Control (AEC)

ECG Modulation is AEC modes for retrospective gated cardiac helical mode.

The image shows a software dialog box titled "mA Control". It contains several input fields and buttons. A yellow rectangular box highlights the "ECG modulated mA" section, which includes a "Full mA Range" label, "Start Phase" (65), "End Phase" (85), "Min" (220), and "Max" (500) fields. Below this, there is a "Manual mA" field set to 500. At the bottom of the dialog are "OK" and "Cancel" buttons.

Parameter	Value
Start Phase	65
End Phase	85
Min	220
Max	500
Manual mA	500

Dose Modulation and Reduction



## *Image Quality Reference Parameter*

---

- Is the AEC parameter that is set by the user to define the desired level of image quality
- Changing the Image Quality Reference Parameter will affect the  $CTDI_{vol}$

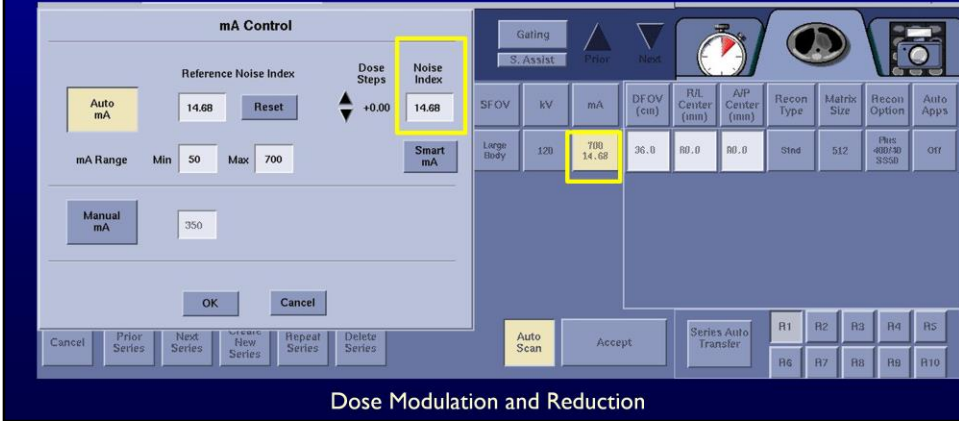
**The effect on  $CTDI_{vol}$  when changing the Image Quality Reference Parameter is vendor dependent**

Dose Modulation and Reduction



## GE Healthcare: Image Quality Reference Parameter

Noise Index (not reference noise index) defines image noise (Std. Dev.) in the acquisition when AutomA or SmartmA is enabled.



Noise Index is Image Quality Parameter which sets the image noise in the image. Scout is used to determine patient attenuation characteristics and size and along with Noise Index the mA per rotation for the acquisition is determined.



## Image Quality Reference Parameter

- A change in the Image Quality Reference Parameter will affect the  $CTDI_{vol}$
- Setting the parameter for “increased” image quality (e.g., lower noise) will result in more dose
  - Decreasing the Noise Index will result in an increase in the  $CTDI_{vol}$
- Setting the parameter for “decreased” image quality (e.g., more noise) will result in less dose
  - Increasing the Noise Index will result in a decrease in the  $CTDI_{vol}$

Dose Modulation and Reduction

Decreasing the Noise Index means lower noise in the image which means increase mA resulting in increased  $CTDI_{vol}$ .

Increasing the Noise Index (NI) means higher noise in the image which means decreasing mA resulting in decreased  $CTDI_{vol}$ .

Noise Index will vary based on the slice thickness selected due to the difference in image noise relative to slice thickness. The same NI should never be used across all slice thicknesses.





## *Longitudinal Tube Current Modulation*

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- Is an AEC feature that adjusts the Tube Current as patient attenuation changes in the longitudinal direction
- The CT Localizer Radiograph is used to estimate patient attenuation

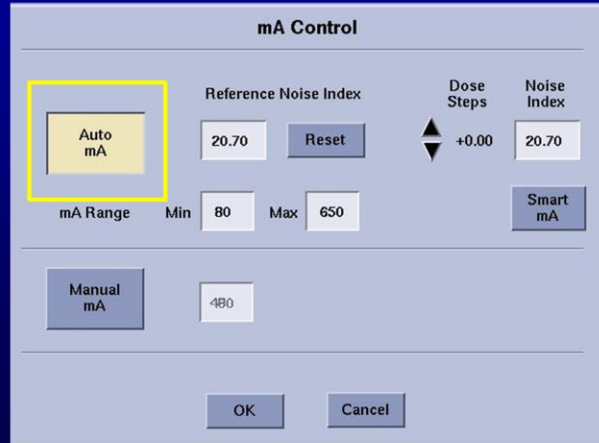
**The use of Longitudinal Tube Current Modulation may decrease or increase  $CTDI_{vol}$  depending on the patient size and body area imaged and image quality requested**

Dose Modulation and Reduction



## GE Healthcare: Longitudinal Tube Current Modulation

AutomA is modulation along Z



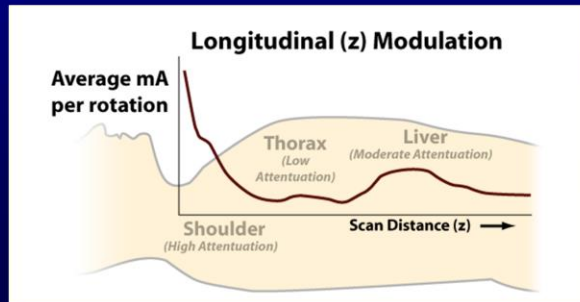
Dose Modulation and Reduction

AutomA modulates the mA along Z for each rotation.



## Longitudinal Tube Current Modulation

- Longitudinal Tube Current Modulation (AutomA) uses information from
  - One view localizer scans (uses the last localizer taken).



Dose Modulation and Reduction



## *Angular and Longitudinal Tube Current Modulation*

- Is an AEC feature that incorporates the properties of both **Angular and Longitudinal Tube Current Modulation** to
  - Adjust the Tube Current based on the patient's overall attenuation
  - Modulate the Tube Current in the angular (X-Y) and longitudinal (Z) dimensions to adapt to the patient's shape

**The use of Angular and Longitudinal Tube Current Modulation may decrease or increase  $CTDI_{vol}$  depending on the patient size and body area imaged and image quality requested**

Dose Modulation and Reduction



## GE Healthcare: Angular and Longitudinal Tube Current Modulation

SmartmA modulates the mA in X, Y and Z

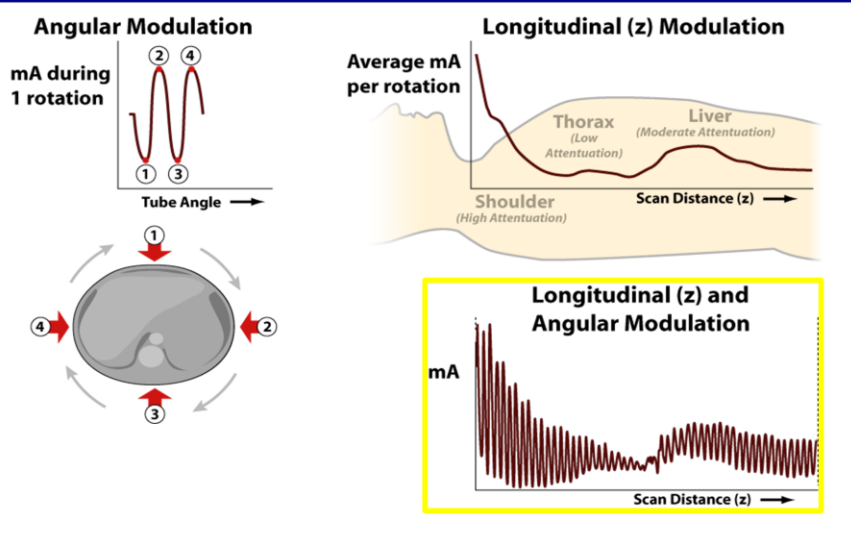
The image shows a software interface titled "mA Control" with several sections:

- Auto mA:** A yellow button on the left.
- Reference Noise Index:** A text box containing "20.70" and a "Reset" button.
- Dose Steps:** A vertical double-headed arrow icon and a text box containing "+0.00".
- Noise Index:** A text box containing "20.70".
- mA Range:** A section with "Min" and "Max" labels, and text boxes containing "80" and "650" respectively.
- Smart mA:** A yellow button on the right, highlighted with a yellow border.
- Manual mA:** A grey button on the left, with a text box containing "480" to its right.
- Buttons:** "OK" and "Cancel" buttons at the bottom.

Dose Modulation and Reduction



# Angular and Longitudinal Tube Current Modulation



Dose Modulation and Reduction



## *ECG-Based Tube Current Modulation*

---

- Is an AEC feature used with prospectively gated cardiac imaging that adjusts the Tube Current based on the phase within the cardiac cycle
- There are important heart rate considerations to take into account when using prospective gating

**The use of ECG-Based Tube Current Modulation with prospective gating will decrease  $CTDI_{vol}$  compared to retrospective gating**

Dose Modulation and Reduction



## GE Healthcare: ECG-Based Tube Current Modulation

ECG Modulation changes mA based on target phase range for Full mA

The image shows a software dialog box titled "mA Control" with a light blue background. It contains several input fields and buttons. A yellow rectangular box highlights the "Full mA Range" section, which includes "Start Phase" (65) and "End Phase" (85) fields. Below this, there are "Min" and "Max" labels. The "mA Range" section has "220" and "500" fields. The "Manual mA" section has a "500" field. At the bottom, there are "OK" and "Cancel" buttons. The text "Dose Modulation and Reduction" is visible at the very bottom of the dialog box.

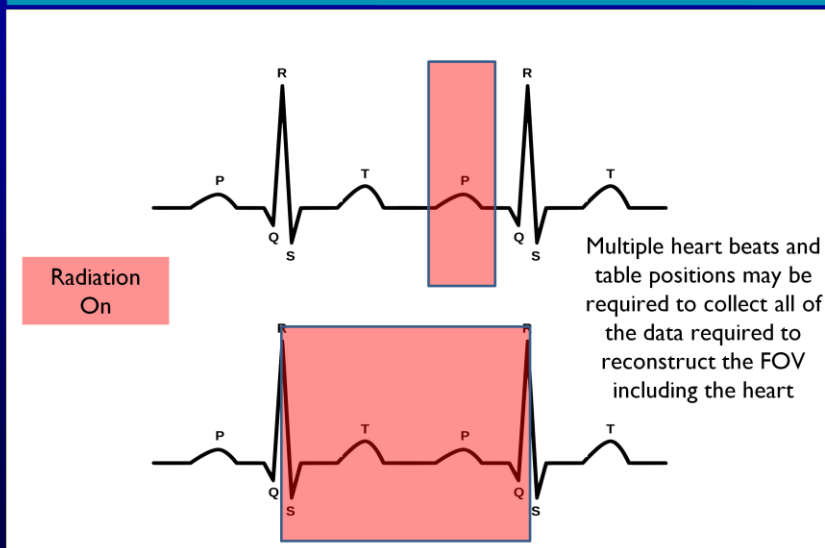
Control	Value
ECG modulated mA	Enabled
Full mA Range Start Phase	65
Full mA Range End Phase	85
mA Range Min	220
mA Range Max	500
Manual mA	500

ECG Modulation modulates the mA over the R-R interval providing full/max mA for specified phase range and modulates mA lower for rest of the phases. ECG Modulation is most beneficial in providing a dose savings when low heart rates are encountered.





## ECG-Based Tube Current Modulation



Dose Modulation and Reduction



## *Organ-Based Tube Current Modulation*

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- Is an AEC feature that allows for the tube current to be decreased or turned off over radiosensitive organs on the patient periphery, such as the breasts or eye lenses
- To maintain image quality, tube current may need to be increased at other view angles

**The use of Organ-Based Tube Current Modulation may reduce the absorbed dose to organs at the surface of the body but may increase the absorbed dose to other organs**

Dose Modulation and Reduction



# GE Healthcare: Organ-Based Tube Current Modulation

## Organ Dose Modulation

The screenshot displays two overlapping windows from a GE Healthcare software interface. The 'ODM Information' window is in the foreground, showing a yellow box around the 'On' radio button. The 'mA Table Information' window is partially visible behind it, showing a table of scan parameters. A yellow circle highlights the 'ODM' button in the top toolbar, with a white arrow pointing to the 'mA' column in the table below. The 'mA' column contains values like '440 DR 15.00" ODM' and '440 DR 21.21" ODM', which are also highlighted with yellow boxes.

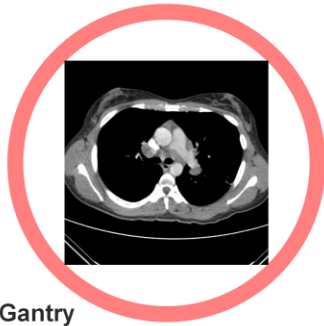
Scan #	A	R	P	L
1*	96	133	138	133
2*	99	134	142	134
3*	100	134	143	134
-----				
1	65	69	65	69
2	59	62	59	62
3	50	50	50	50

Dose Modulation and Reduction

Organ Dose Modulation allows for modulation of mA in dose sensitive areas such as the orbit and anterior chest.

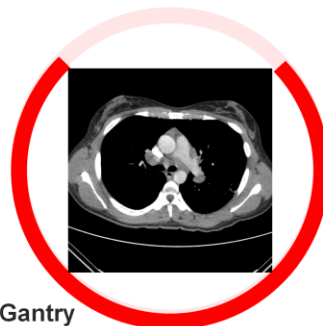


## Organ-Based Tube Current Modulation



Gantry

**Conventional**



Gantry

**Organ-Based Modulation**

Dose Modulation and Reduction

De-Identified Image used with IRB approval



## *Automatic Tube Potential Selection*

---

- Is an AEC feature that selects the tube potential according to the diagnostic task and patient size in order to achieve the desired image quality at a lower  $CTDI_{vol}$

**The use of Automatic Tube Potential Selection is intended to decrease  $CTDI_{vol}$  while achieving the image quality required for a specific diagnostic task and patient attenuation**

Dose Modulation and Reduction



## GE Healthcare: Automatic Tube Potential Selection

In kV Assist, the system suggests the lowest dose kV based on the previously inputted kV, mA, Noise Index, the selected clinical task, selected aggressiveness of dose reduction. If accepted this new kV is constant and the mA and NI are adjusted to provide dose savings

The screenshot displays the kV Assist interface. On the left, a dropdown menu is open, showing four options: 'CTA: CT Angiography', 'Bone: Bone, Non-contrast', 'C+: Soft Tissue, Contrast-enhanced', and 'C-: Soft Tissue, Non-contrast'. The 'C-: Soft Tissue, Non-contrast' option is highlighted. Below this, the 'Selected kV' is set to 80, with buttons for 80, 100, 120, and 140. A 'Manual kV' section also shows buttons for 80, 100, 120, and 140. The 'Dose Savings' section shows 'Normal' selected. A table on the right displays technical parameters for a 'Large Body' scan:

SFOV	kV	mA	Total Exposure Time	Prep Group (s)	ISD (s)	Breath Hold (s)	Breathe Time (s)	Voice Lights Timer	Cine Duration (s)
	80 CTR	650 22.95	0.69	30.0	1.0	N	N	2 T	2.0

At the bottom of the interface, there are buttons for 'Auto Scan', 'End Exam', 'Select New Protocol', 'Next Series', 'Create New Series', 'Repeat Series', and 'One More'. The text 'Dose Modulation and Reduction' is displayed at the bottom center.

kV Assist provides capability to select the kV with lowest dose for the clinical task prescribed using the patient attenuation characteristics obtained from the scout image to determine patient size.



## *Automatic Tube Potential Selection*

---

- Tube Potential is not modulated in the same fashion as Tube Current
- It does not change with different tube positions (view angles) around the patient
- The Tube Potential for a specific patient, anatomic region and diagnostic tasks is selected and held constant for that acquisition, though it may be changed to a different tube potential for a different diagnostic task

Dose Modulation and Reduction



## *Iterative Reconstruction*

---

- Is a feature that uses the information acquired during the scan and repeated reconstruction steps to produce an image with less “noise” or better image quality (e.g., higher spatial resolution or decreased artifacts) than is achievable using standard reconstruction techniques

**The use of Iterative Reconstruction by itself may not decrease  $CTDI_{vol}$ ; with use of Iterative Reconstruction, image quality will change and this may allow a reduction in the  $CTDI_{vol}$  by adjusting the acquisition parameters used for the exam**

Dose Modulation and Reduction



AAPM Working Group on Standardization of CT Nomenclature and Protocols

# GE Healthcare: Iterative Reconstruction

## ASiR – Adaptive Statistical Iterative Reconstruction

Dose Modulation and Reduction

ASiR is a image noise (std. dev.) reduction tool which allows user to reduce image noise for existing parameters to improve image quality or increase image noise through reduction in dose and then use ASiR to reduce image noise to return to similar image quality.



## GE Healthcare: *Iterative Reconstruction*

- Iterative Reconstruction using ASiR is completed using Projection Data
- Changing the % of ASiR will affect the resultant image quality; it **WILL NOT** affect the  $CTDI_{vol}$  of the scan
- In consultation, the radiologists and medical physicists may adjust the acquisition parameters for studies reconstructed using ASiR based on the imaging task and patient population, dose concerns, and the needs of the interpreting radiologist(s)

Dose Modulation and Reduction

ASiR is an iterative reconstruction mode which use scan date to create a model and then blend the noise reduced image model and original image model to create images with lower image noise.



## GE Healthcare: *Iterative Reconstruction*

- Iterative Reconstruction using Veo A Model Based Approach
- Turning On Veo will affect the resultant image quality; it WILL NOT affect the  $CTDI_{vol}$  of the scan
- In consultation, the radiologists and medical physicists may adjust the acquisition parameters for studies reconstructed using Veo based on the imaging task and patient population, dose concerns, and the needs of the interpreting radiologist(s)

Dose Modulation and Reduction

Vevo is a model based iterative reconstruction which can provide high quality image at low doses.



## *Dose Display*

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- Information about the  $CTDI_{vol}$  planned for each scan is typically displayed before the exam on the user console
- Information about the  $CTDI_{vol}$  delivered by each scan is typically reported in a data page or DICOM structured dose report
- Dose information provided after the exam typically also includes the DLP and the CTDI phantom size. These may also be included in information displayed before the scan.



## *Display of Planned $CTDI_{vol}$*

---

- $CTDI_{vol}$  is displayed before a study is performed based on the selected technique parameters
- It is important to check  $CTDI_{vol}$  before a study is performed to ensure that the output of the scanner is appropriate for the specific patient and diagnostic task

**$CTDI_{vol}$  is displayed for each planned acquisition**

Dose Display



## GE Healthcare: *Display of Planned CTDI<sub>vol</sub>*

### Dose Information Area on View Edit screen

Dose Information				
Images	CTDI <sub>vol</sub> mGy	DLP mGy·cm	Dose Eff. %	Phantom cm
1-61	6.68	243.82	92.60	Body 32
Projected series DLP:			243.82	mGy·cm
Accumulated exam DLP:			0.00	mGy·cm

Dose Display

Dose Information area is always available on the View Edit screen to review dose information for the current proposed acquisition and the Accumulated exam DLP if additions series have already been acquired.



## *Post Study Data Page*

---

- Following the completion of a study, a **Post Study Data Page** is created that includes information on the delivered  $CTDI_{vol}$  and DLP and the phantom size used to calculate these values
- Information is displayed for each series

Dose Display



## GE Healthcare: Post Study Data Page

### Dose Report – Series 999

Patient Name: System Use			Exam no: 198		
Accession Number:			Nov 22 2011		
Patient ID: 22345			Discovery CT750 HD		
Exam Description: Chest					
Dose Report					
Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I20.250-I285.250	6.29	207.51	Body 32
Total Exam DLP:				207.51	
Attention					
1/1					

W:1 L:-2

Dose Display

Dose Report provides CTDIvol, DLP, Phantom Size along with the Scan Type, Scan Range for each series/group and Total Exam DLP.





## *Post Study Data Page - $CTDI_{vol}$*

---

- $CTDI_{vol}$  is displayed for each series after a study is performed and is calculated based on the technique factors used to acquire the data
- It is useful to check  $CTDI_{vol}$  after a study is performed to ensure that the output of the scanner was as expected

**$CTDI_{vol}$  is displayed for each completed acquisition**

Dose Display



## *Post Study Data Page - DLP*

---

- DLP is displayed for each series after a study is performed and is calculated based on the technique factors and scan length used

**DLP is displayed for each completed acquisition and is typically summed for all of the acquisitions**

Dose Display



## *Post Study Data Page – CTDI Phantom*

---

- The CTDI Phantom used for each acquisition in the study is typically displayed
- Different phantoms may be used to calculate the  $CTDI_{vol}$  for different acquisitions in the same study (and may vary by vendor)
  - Head and C-Spine Example
    - Body Phantom used to report  $CTDI_{vol}$  for C-Spine portion of exam
    - Head Phantom used to report  $CTDI_{vol}$  for Head portion of exam

Dose Display



## *Summing Dose Report Values*

- $CTDI_{vol}$  values for separate series are NOT to be summed to give a “total”  $CTDI_{vol}$  for a study
  - This is especially true if the series cover different anatomic regions
- DLP is typically summed over all series in the Post Study Data Page to provide an estimate of the total patient exposure
  - Extreme care should be taken when considering summed DLPs because different phantoms may have been used to calculate the  $CTDI_{vol}$  values used to determine DLP
- A medical physicist should be contacted if patient specific dose estimates are required

Dose Display



## *Dose Notification Levels*

---

- **Notification Levels** may be set on a CT scanner for each series within an exam protocol
- If the planned  $CTDI_{vol}$  is above the **Notification Level** and triggers the notification, the user has the opportunity to edit or confirm the technique settings
- **Notification Levels** may be exceeded when appropriate for a specific patient or diagnostic task (e.g., in very large patients or contrast bolus monitoring scans)

Dose Display



# GE Healthcare: Dose Notification Levels

## Dose Check – CTDIvol and DLP notification levels

### Dose Check Management Tool

**NV (Notification Value) Checking**

CTDIvol

DLP

**AV (Alert Value) Checking**

CTDIvol (mGy)

DLP (mGy·cm)

Add Age Threshold

**Protocol Change Control**

On

Save

### Dose Check Setup

Info

Images	CTDIvol mGy	DLP mGy·cm	NV	
			CTDIvol	DLP
1-321	13.11	347.37	16	522

Est. max Z location CTDIvol: 13.11 mGy

Projected series DLP: 347.37 mGy·cm

Accumulated exam DLP: 0.00 mGy·cm

Dose Display

The Dose Notification feature complies with the NEMA XR-25 standard.

Dose Check Management allows user to enable Notification Value checking. In each protocol, the user can define a Notification Value for CTDIvol and DLP based on the clinical goal of the protocol.



## *Dose Alert Levels*

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- **Dose Alert Levels** require specific action by the operator to continue scanning
- **Dose Alert Levels** are typically much higher than Notification Levels and take into account all series within the exam
- Triggering a **Dose Alert** requires that the operator confirm the protocol and settings are correct by entering in his or her name. Optionally, sites may require that the operator provide a brief explanation in the provided field

Dose Display



## GE Healthcare: *Dose Alert Levels*

Dose Check Alert Values for CTDIvol and DLP can be set for Adult and Pediatric

Dose Display

The Dose Alert feature complies with the NEMA XR-25 standard.

Dose Check Alert Values can be set for CTDIvol and DLP for Adult and Pediatrics in the Dose Check Management screen.





## *Radiation Dose Structured Reports*

---

- Radiation Dose Structured Reports (RDSRs) are provided in newer software versions in a defined DICOM format
- They provide the most complete set of information regarding the irradiating events
- The reports are very detailed and require an RDSR viewer for easy visualization of relevant information

Dose Display



## Questions

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- Please contact the medical physicist providing support for your CT practice, your lead technologist, supervising radiologist or manufacturer's application specialist with questions regarding these important topics and concepts.



## Acknowledgements

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- **AAPM**
  - Dianna Cody, Dustin Gress, Michael Heard, Jim Kofler, Cynthia McCollough, Mike McNitt-Gray, Bob Pizzutiello, Mark Supanich
- **ACR**
  - Mark Armstrong, Penny Butler, Dina Hernandez
- **ASRT**
  - Virginia Lester
- **DICOM**
  - David Clunie, Kevin O'Donnell
- **FDA**
  - Thalia Mills

A special thank you to Dr. Mark Supanich for his considerable efforts in leading the working group in developing these slides.



## Acknowledgements

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- GE
  - John Jaeckle
- Hitachi
  - Mark Silverman
- Philips
  - Amar Dhanantwari
- Neusoft
  - Keith Mildemberger
- NeuroLogica
  - Donald Fickett
- Siemens
  - Christianne Liedecker
- Toshiba
  - Kristen Boedecker
- MITA
  - Brian Abraham