



*AAPM Computed Tomography Radiation  
Dose Education Slides  
Toshiba 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**.



## *Toshiba Disclaimer*

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- Information in this presentation is a product of the AAPM except where otherwise indicated
- The Toshiba screen captures in this presentation represent the Aquilion ONE, software version 4.74 ER004.

The Toshiba screen captures in this presentation represent the Aquilion ONE, software version 4.74 ER004.



## *Vendor Specific Slide Details*

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- The presence of a vendor name in the title 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



## Vendor: *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

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

120 kVp at 200 mAs



32 cm  
Phantom

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

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

What is Dose?



## Size Specific Dose Estimate (SSDE)

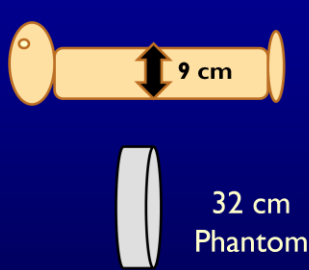
- AAPM report 204 describes a method to calculate SSDE using  $CTDI_{vol}$
- Conversion factors based on patient size (e.g., AP or lateral width, effective diameter) are provided to **estimate** patient dose for a patient of that size
- However, SSDE is still not the exact patient dose, as factors such 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?



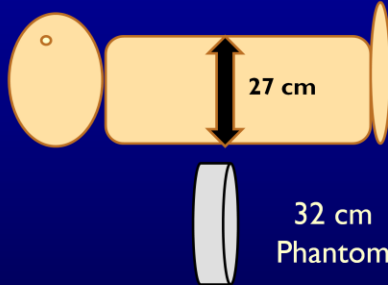
## How is $CTDI_{vol}$ related to patient dose?

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.

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

# Toshiba: Scan Mode

## Scan Mode

The screenshot displays the 'Scan Mode' configuration window. It includes a table for the scan sequence, a list of scan mode options, and various technical parameters for the selected mode.

No.	Start	Start Time	Wait	Start Pos.	End Pos.	Scan Mode
1	P	***	***	0.0	800.0	DualScano
2	A	***	***	800.0	0.0	DualScano
3	P		0.0	0.0	420.0	Helical

**Scan Mode Options:** Scan Mode, S&S, S&V, DE-Vol, DE-Hel, Helical, vsp, GG-Hel, GR-Hel, Volume, Dy-Volume, ScanStart.

**Parameters for Helical mode:**

- Thickness: 0.5 x 160
- kV: 120
- mA: R \*\*\*
- Rot. Time: 0.5
- Range: 420.0
- Max. Range: 1820.0
- D-FOV: 400.0 (L)
- Eff. mAs: \*\*\*
- Total ScanTime: 4.0
- Direction: OUT
- CE: OFF
- Focus: Small
- Comment: Non
- Contrast: [Dropdown]
- Max. Exp. Time: 14.03

Buttons: Copy, New Scan, Delete, BreathControl, OLP, sim., Save, Cancel.

*The medical staff is responsible for patient radiation exposure and safety.*

Acquisition Parameter Settings Provided by Toshiba

In this example, S&S, S&V, and Volume are Axial modes (Volume mode refers to an axial scan of a length  $\geq 4\text{cm}$  volume with thin acquisition slice thicknesses). Helical, GG-Hel, and GR-Hel are Helical scan modes. Dy-Volume is a Dynamic scan mode. Slide provided by Toshiba Medical Systems



## *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



## Toshiba: Table Feed/Increment

### Couch Movement

Protocol	Scan Details	Recon. Details	Dose	
Thickness 8.0 x 4	kV 120	mA 10	Rot. Time 0.5	Range 224.0
Sure Exp. 3D OFF	D-FOV 400.0 (L)	Eff. mAs 5	Couch Movement OUT 32.0	Direction OUT
	CE OFF	Focus Small	Comment Non Contrast	

Acquisition Parameter Settings

Provided by Toshiba

Couch Movement is in the unit of mm/rotation.  
Slide provided by Toshiba Medical Systems



## 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  $16 \times 1.25\text{mm}$

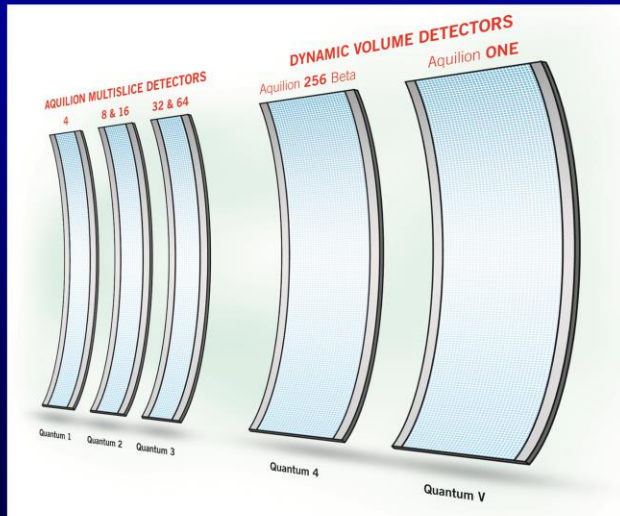
**Users should monitor  $CTDI_{vol}$  values when changing detector configuration**

Acquisition Parameter Settings





## Toshiba: *Detector Configuration*



Acquisition Parameter Settings

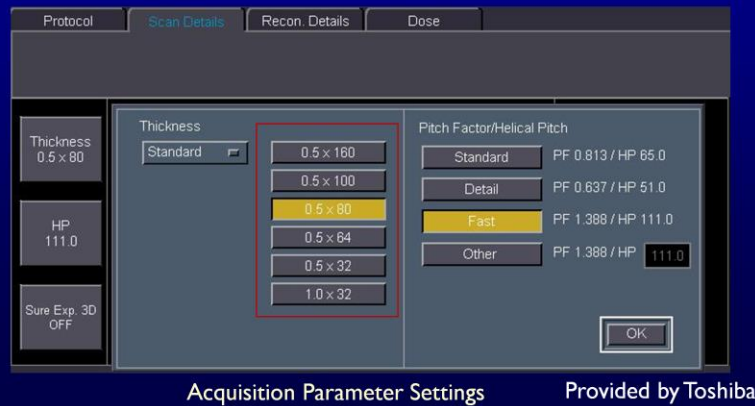
Provided by Toshiba

Slide provided by Toshiba Medical Systems



## Toshiba: *Detector Configuration*

The Detector Configuration (displayed as T x n) is selected by clicking on the “Thickness” box under the “Scan Details” tab.



In the highlighted example, 0.5mm is the channel thickness (T) and 80 is the number of channels (n)

Slide provided by Toshiba Medical Systems



## *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



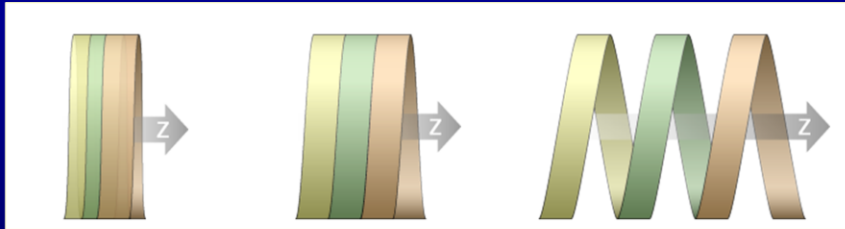
## Pitch

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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



## 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

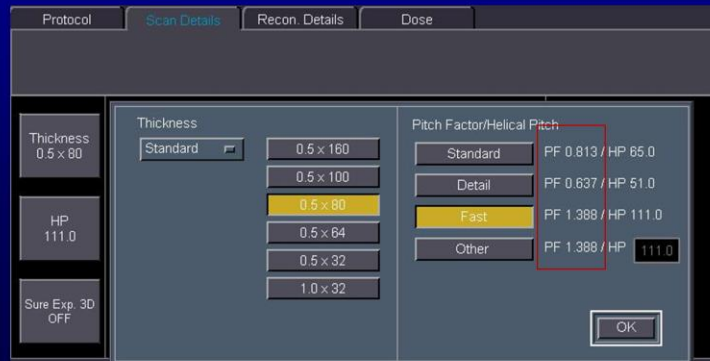
Acquisition Parameter Settings



## Toshiba: Pitch

“Pitch Factor” or “PF”

Helical Pitch or “HP” is defined as the Table Feed per gantry rotation divided by the channel thickness (T)



Acquisition Parameter Settings

Provided by Toshiba

PF and HP are related to each other by the number of channels. Multiply the PF by the number of channels to get HP.

Slide provided by Toshiba Medical Systems



## *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)

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

**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*

---

- $CTDI_{vol}$  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





## Toshiba: Exposure Time per Rotation

### Rot. Time

Protocol	Scan Details	Recon. Details	Dose	
Thickness 0.5 x 80	kV 120	mA 300	Rot. Time 0.5	Range 420.0
HP 85.0	D-FOV 400.0 (L)	Eff. mAs 185	Total ScanTime 7.3	Direction OUT
Sure Exp. 3D OFF	CE OFF	Focus Large	Comment Non	Max. Exp. Time 29.985
			Contrast	

Acquisition Parameter Settings

Provided by Toshiba

Slide provided by Toshiba Medical Systems



## *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



## Toshiba: Tube Current

mA

Protocol	Scan Details	Recon. Details	Dose	
Thickness 0.5 x 80	kV 120	mA 300	Rot. Time 0.5	Range 420.0
HP 85.0	D-FOV 400.0 (L)	Eff. mAs 185	Total ScanTime 7.3	Direction OUT
Sure Exp. 3D OFF	CE OFF	Focus Large	Comment Non	Max. Exp. Time 29.985
			Contrast	

Acquisition Parameter Settings

Provided by Toshiba

Slide provided by Toshiba Medical Systems



## Tube Potential

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

$$CTDI_{vol} \propto \left( \frac{kV_{new}}{kV_{old}} \right)^n \quad n \approx 2 \text{ to } 3$$

Acquisition Parameter Settings



# Toshiba: Tube Potential

kV

Protocol	Scan Details	Recon. Details	Dose	
Thickness 0.5 x 80	kV 120	mA 300	Rot. Time 0.5	Range 420.0
HP 85.0	D-FOV 400.0 (L)	Eff. mAs 185	Total ScanTime 7.3	Direction OUT
Sure Exp. 3D OFF	CE OFF	Focus Large	Comment Non	Max. Exp. Time 29.985
			Contrast	

Acquisition Parameter Settings

Provided by Toshiba

Slide provided by Toshiba Medical Systems



## *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



## Toshiba: Tube Current Time Product

Eff. mAs for axial scans

Protocol	Scan Details	Recon. Details	Dose
Thickness 8.0 x 4	kV 120	mA 10	Rot. Time 0.5
	D-FOV 400.0 (L)	Eff. mAs 5	Range 224.0
Sure Exp. 3D OFF	CE OFF	Focus Small	Couch Movement OUT 32.0
			Direction OUT
			Comment Non
			Contrast

Acquisition Parameter Settings

Provided by Toshiba

Slide provided by Toshiba Medical Systems



## *Effective Tube Current Time Product*

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

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

Acquisition Parameter Settings





## Toshiba: Effective Tube Current Time Product

Eff. mAs

Protocol	Scan Details	Recon. Details	Dose	
Thickness 0.5 x 80	kV 120	mA 300	Rot. Time 0.5	Range 420.0
HP 85.0	D-FOV 400.0 (L)	Eff. mAs 185	Total ScanTime 7.3	Direction OUT
Sure Exp. 3D OFF	CE OFF	Focus Large	Comment Non	Max. Exp. Time 29.985
			Contrast	

Acquisition Parameter Settings

Provided by Toshiba

Slide provided by Toshiba Medical Systems



## *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



## Toshiba: Field of Measurement

### Calib-FOV



Acquisition Parameter Settings

Provided by Toshiba

The calibrated FOV is denoted by a letter: LL (50cm), L (40cm), M (32cm), S (24cm), SS (18cm)

Note: for Large Bore scanners: XL(70cm), LL(55cm), L(40cm), M(32cm), S(24cm)

Slide provided by Toshiba Medical Systems



## *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



## 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



## Toshiba: Automatic Exposure Control (AEC)

### Sure Exp. 3D

Protocol	Scan Details	Recon. Details	Dose
Thickness 0.5	kV 120	mA RP ***	Rot. Time 0.35
W-Volume OFF	D-FOV 220.0 (M)	Eff. mAs ***	Range 120.0
Sure Exp. 3D	CE ON	Focus Large	Total ScanTime 1.224
		Direction OUT	Comment CTA

Dose Modulation and Reduction

Provided by Toshiba

Toshiba's AEC is called <sup>SURE</sup>Exposure3D.

Slide provided by Toshiba Medical Systems





## *Image Quality Reference Parameter*

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- 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



## Toshiba: Image Quality Reference Parameter

On the Toshiba console a “Preset” SURE<sup>EX</sup> Exposure3D setting or manual “SD” should be selected by the user



Dose Modulation and Reduction

Provided by Toshiba

The target Image Quality setting can be chosen by clicking on the “Sure Exp. 3D” box.  
Slide provided by Toshiba Medical Systems



## *Image Quality Reference Parameter*

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- 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 SD 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 SD will result in a decrease in the  $CTDI_{vol}$

Dose Modulation and Reduction



## *Angular Tube Current Modulation*

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- Is an AEC feature that adjusts the Tube Current as the x-ray tube rotates around the patient to compensate for attenuation changes with view angle
- **Angular Tube Current Modulation** is used to adjust the Tube Current to attempt to deliver similar dose to the detector at all view angles

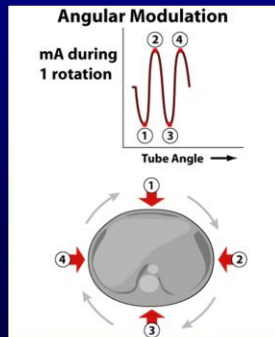
**The use of Angular Tube Current Modulation may decrease or increase  $CTDI_{vol}$  depending on the patient size and body area imaged and image quality requested**

Dose Modulation and Reduction



## Toshiba: Angular Tube Current Modulation

- Angular Tube Current Modulation (part of SURE<sup>RE</sup> Exposure3D) uses information from
  - Two view scanograms (i.e. “DualScano”)



Dose Modulation and Reduction



## Toshiba: Angular Tube Current Modulation

Angular Tube Current Modulation is controlled by SURE<sup>EX</sup>posure3D



Dose Modulation and Reduction

Provided by Toshiba

Slide provided by Toshiba Medical Systems



## *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

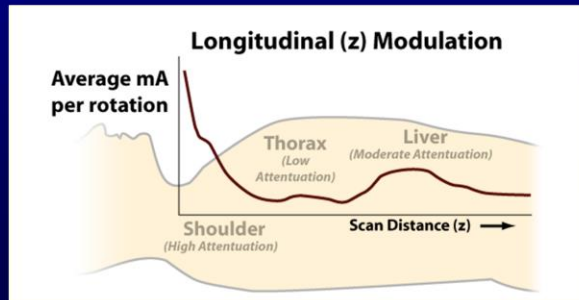
**The use of Longitudinal Tube Current Modulation may decrease or increase  $CTDI_{vol}$  depending on the patient size and body area imaged and image quality requested**

Dose Modulation and Reduction



## Toshiba: *Longitudinal Tube Current Modulation*

- Longitudinal Tube Current Modulation (part of SURE<sup>EX</sup>posure3D) uses information from
  - One or Two view scanograms



Dose Modulation and Reduction





## Toshiba: Longitudinal Tube Current Modulation

Longitudinal Tube Current Modulation is automatically turned on when SURE<sup>EX</sup>posure3D is enabled



Dose Modulation and Reduction

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## *Angular and Longitudinal Tube Current Modulation*

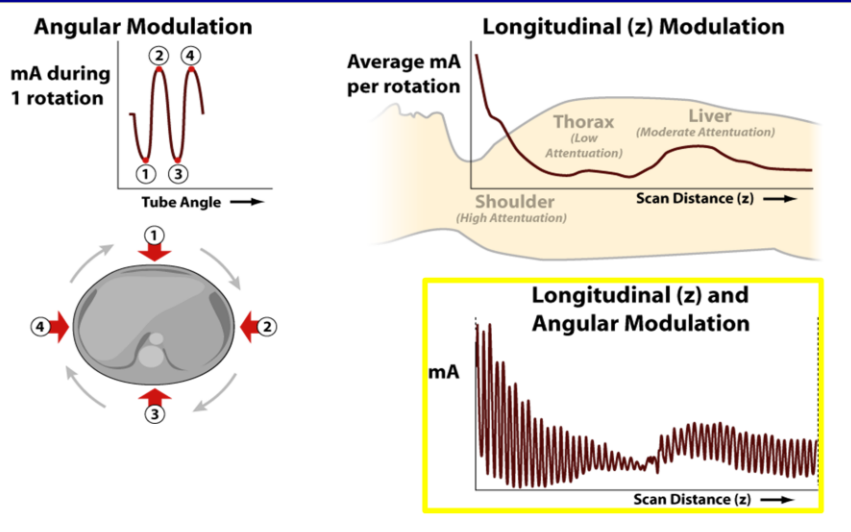
- Is an AEC feature that incorporates the properties of both **Angular and Longitudinal Tube Current Modulation** to
  - Adjust the Tube Current based on the patient's overall attenuation
  - Modulate the Tube Current in the angular (X-Y) and longitudinal (Z) dimensions to adapt to the patient's shape

**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



# Angular and Longitudinal Tube Current Modulation



Dose Modulation and Reduction



## Toshiba: Angular and Longitudinal Tube Current Modulation

SURE<sup>EX</sup>posure3D (Longitudinal Tube Current Modulation is always on)



Dose Modulation and Reduction

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## *ECG-Based Tube Current Modulation*

---

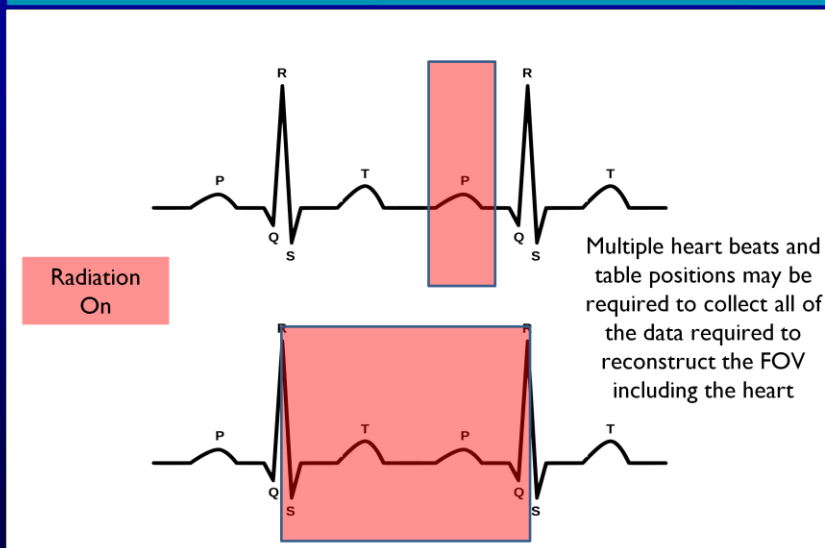
- Is an AEC feature used with prospectively gated cardiac imaging that adjusts the Tube Current based on the phase within the cardiac cycle
- There are important heart rate considerations to take into account when using prospective gating

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

Dose Modulation and Reduction



## ECG-Based Tube Current Modulation



AAPM Working Group on Standardization of CT Nomenclature and Protocols


# Toshiba: ECG-Based Tube Current Modulation

## SURECardio

Scan Sequence  Time Sequence

Protocol Scan Details Recon. Details Dose

SureCardio (Volume)

Prospect CTA  Phase 70 - 80 %  
mA : \*\*\*

Heart rate (bpm) 60 Breath hold time 10.0

Breath Ex. Time resolution 175.00 ms ImageXact OFF

Heart rate acq. Detail Beat 1(Half)

Thickness 0.5

W-Volume OFF

Sure Exp. 3D

kV	mA	Rot. Time	Range
120	RP ***	0.35	120.0

D-FOV	Eff. mAs	Total ScanTime	Direction
220.0 (M)	***	1.224	OUT

CE ON Focus Large Comment CTA

Dose Modulation and Reduction Provided by Toshiba

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## *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





## Toshiba: *Iterative Reconstruction*

- Toshiba console designation: “AIDR 3D”



Dose Modulation and Reduction

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## Toshiba: *Iterative Reconstruction*

- Iterative Reconstruction using AIDR 3D is completed using an Image, Projection Data, and Model-Based Approach
- Changing/Turning On AIDR 3D will affect the resultant image quality; it CAN affect the  $CTDI_{vol}$  of the scan
- In consultation, the radiologists and medical physicists may adjust the acquisition parameters for studies reconstructed using AIDR 3D based on the imaging task and patient population, dose concerns, and the needs of the interpreting radiologist(s)

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Dose Modulation and Reduction

AIDR3D is integrated with the mA modulation system, <sup>SURE</sup>Exposure3D. Therefore, when AIDR is selected prior to scanning, the mA and  $CTDI_{vol}$  will be affected.  
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## *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



## Toshiba: Display of Planned CTDI<sub>vol</sub>

Under "Dose" tab

	Planned Dose	Notification Value	
Scan Total	CTDI vol <b>7.5</b> mGy	<input type="text"/> mGy	Dose Calculation Method  32cm diameter Z-Axis Efficiency <input type="text"/> %
	DLP <b>399.8</b> mGy.cm	<input type="text"/> mGy.cm	
Protocol Total	Cumulative CTDI vol <b>7.5</b> mGy		
	DLP <b>399.8</b> mGy.cm		

Dose Display

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## *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



## *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



## Toshiba: Post Study Data Page - $CTDI_{vol}$

### Exposure Record (second page)

Study ID : 69	Study Date : 2009.11.20	(P. 2)		
Accession Number : 69				
<< Detail Information >>				
1.2 Phase Liver 5mm (0.5mm x 64)				
	Total mAs	Exposure Time	$CTDI_{vol}$	DLP
SCANOSCOPE [2]	565.00	7.56		
HELICAL_CT	973.00	4.87	14.60 (Body)	377.00 (Body)
HELICAL_CT	973.00	4.87	14.60 (Body)	377.00 (Body)

Dose Display

Provided by Toshiba

“Body” in parentheses refers to use of the 32cm CTDI phantom to determine  $CTDI_{vol}$ .

“Head” would refer to the 16cm phantom.

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## *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



## Toshiba: Post Study Data Page - DLP

### Exposure Record (second page)

Study ID : 69	Study Date : 2009.11.20	(P. 2)		
Accession Number : 69				
<< Detail Information >>				
1.2 Phase Liver 5mm (0.5mm x 64)				
	Total mAs	Exposure Time	CTDIvol	DLP
SCANOSCOPE [2]	565.00	7.56		
HELICAL_CT	973.00	4.87	14.60 (Body)	377.00 (Body)
HELICAL_CT	973.00	4.87	14.60 (Body)	377.00 (Body)

Dose Display

Provided by Toshiba

“Body” in parentheses refers to use of the 32cm CTDI phantom to determine  $CTDI_{vol}$ .

“Head” would refer to the 16cm phantom.

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## *Post Study Data Page – CTDI Phantom*

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- 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



## Toshiba: Post Study Data Page – CTDI Phantom

### Exposure Record (second page)

Study ID : 69	Study Date : 2009.11.20	(P. 2)		
Accession Number : 69				
<< Detail Information >>				
1.2 Phase Liver 5mm (0.5mm x 64)				
	Total mAs	Exposure Time	CTDIvol	DLP
SCANOSCOPE [2]	565.00	7.56		
HELICAL_CT	973.00	4.87	14.60 (Body)	377.00 (Body)
HELICAL_CT	973.00	4.87	14.60 (Body)	377.00 (Body)

Dose Display

Provided by Toshiba

“Body” in parentheses refers to use of the 32cm CTDI phantom to determine  $CTDI_{vol}$ .

“Head” would refer to the 16cm phantom.

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## 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*

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- **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



## Toshiba: *Dose Notification Levels*

Notification levels are user configurable

DOSE NOTIFICATION				
One or more elements in this exam plan will exceed the dose notification level that has been set.				
Element	Predicted CTDvol	Predicted DLP	Notification CTDvol	Notification DLP
Helical	11.4 mGy	342 mGy.cm	30 mGy	1000 mGy.cm
Helical	14.6 mGy	1018 mGy.cm	30 mGy	1000 mGy.cm

Edit OK

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

Dose Display

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## *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





## Toshiba: Dose Alert Levels

Default alert level is 1000 mGy

**! DOSE ALERT**  
A dose alert value will be exceeded !

Proceeding with this exam will exceed the dose alert level that has been set.

	Predicted Dose	Alert Level
Cumulative CT DIvol	1004.0 mGy	1000.0 mGy

**Input Name**

Name

Password

**Input Diagnostic Reason**

Reason

- Large patient
- Exceptional image quality required
- Large number of series required
- Free text...

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

Dose Display

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## *Radiation Dose Structured Reports*

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- 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.



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