REPORTING OF DOSE IN COMPUTED TOMOGRAPHY

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CONFUSION OF "LOW DOSE" CT

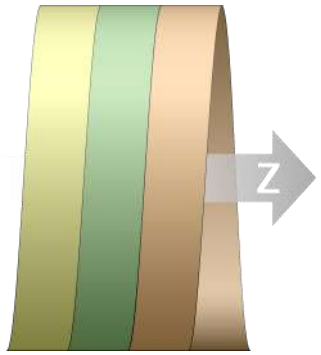
- Temporal variation
- Geographic variation
- Variation between patients
- Conceptual misinterpretation
- **Radiology** requirement
- **Medical Physics** requirement

CT DOSE UNITS

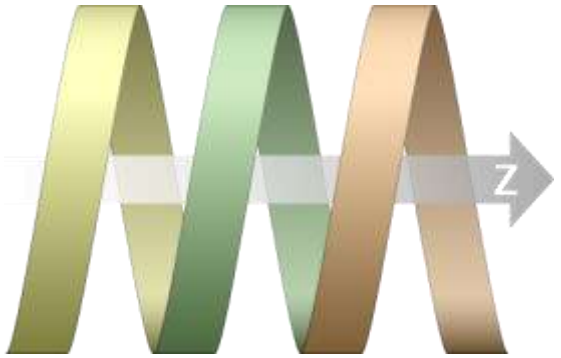
- $CTDI_{100} = \frac{1}{nT} \int_{z=-50\,mm}^{+50\,mm} D(z)\ dz$
- $CTDI_W = 2/3\ (CTDI_{100})^{center} + 1/3\ (CTDI_{100})^{periphery}$
- $CTDI_{vol} = CTDI_w\ /\ Pitch$

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

ATTRIBUTES OF $CTDI_{VOL}$

- Amount of radiation delivered/exam
- Displayed in dose protocol of most scanners
- Defined by standards/regulatory agencies
- Metric used by ACR accreditation program
- Measurement equipment available worldwide
- Universal specification of CT “dose”
- Useful for comparing protocols and scanners for QA
- Useful for ACR Dose Index Registry

LIMITATIONS OF $CTDI_{VOL}$

- Measured with a cylindrical, homogeneous phantom
- Phantom size must be specified (16 or 32cm)
- Reflects dose to air, not tissue
- Does not consider patient size
- Finite length of body phantom provides less scatter
- Integration length (100 mm) insufficient for large beam widths
- Overestimates dose for stationary patients
- Dose-saving technologies may yield false $CTDI_{VOL}$ results
- For same $CTDI_{vol}$ smaller patient will receive higher dose than larger patient

DOSE-LENGTH PRODUCT (DLP)

- $CTDI_{VOL}$ independent of scan length
- DLP = $CTDI_{VOL}$ X scan length
- Units of mGy-cm
- Both $CTDI_{VOL}$ and DLP read from scanner protocol
- Both measures describe scanner output, not patient dose

SIZE-SPECIFIC DOSE ESTIMATE (SSDE)

- Includes influence of patient dimensions
- D_{EFF} = [AP diameter x lateral diameter]$^{1/2}$
- From D_{EFF} obtain f_{SIZE} (Tables 1 & 2 AAPM TG Rept 204)
- SSDE = $CTDI_{VOL}$ x f_{SIZE}
- Provides an approximation of mean dose to patient center (not organ dose)
- Report $CTDI_{VOL}$, DLP, D_{EFF} and SSDE for CT Patients

EFFECTIVE DOSE

- $Dose_{EFF} = S, (D_{ORG} \ X \ w_T)$
- w_T = tissue weighting factor (ICRP 103)
- w_T defined for ICRP reference human
- w_T averaged over all ages and both sexes
- $Dose_{EFF}$ appropriate for radiation protection standards
- $Dose_{EFF}$ should not be used for individual/population risk estimates

ORGAN DOSE

- Cancer Risk = Σ (Organ dose) X (Risk estimate/dose)
- Methods for organ dose estimation (ImPACT, CTExpo, ImpactDose)
- Limitations
  - Patient size differences
  - Scanner variations
  - False results with dose-saving technologies
- Better methods for organ dose estimation needed

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	$CTDI_{vol} \propto 1/Pitch$
Exposure Time Per Rotation	$CTDI_{vol} \propto$ Exposure Time per Rotation
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

- 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

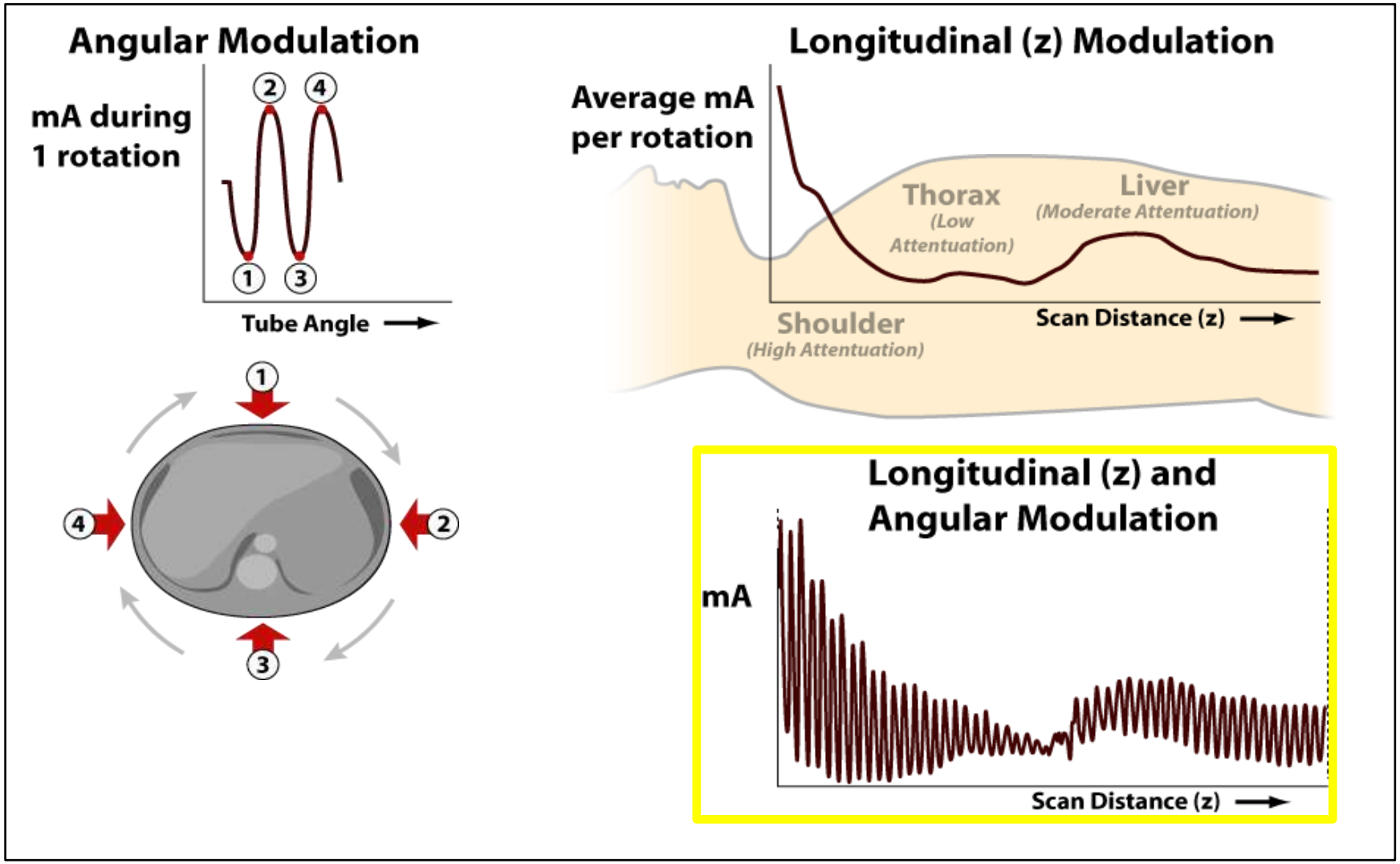
IMAGE QUALITY REFERENCE PARAMETER

- A parameter set by the user to define the desired image quality
- Setting the parameter for improved image quality (lower noise) will increase $CTDI_{vol}$
- Setting the parameter for reduced image quality (more noise) will decrease $CTDI_{vol}$
- The magnitude of change in $CTDI_{vol}$ is vendor dependent

ANGULAR AND LONGITUDINAL TUBE CURRENT MODULATION

- Modulates the tube current in the angular (x–y) dimension to adapt to the patient's attenuation
- Modulates the tube current in the longitudinal (z) dimension to adapt to the patient's attenuation
- Tube current modulation may reduce or increase $CTDI_{vol}$ depending on the patient and body area

ANGULAR AND LONGITUDINAL TUBE CURRENT MODULATION



ECG-BASED TUBE CURRENT MODULATION

- With prospectively-gated cardiac imaging, adjusts tube current based on the phase of the cardiac cycle
- Changes in tube current will reduce $CTDI_{vol}$ compared with retrospective gating

ORGAN-BASED TUBE CURRENT MODULATION

- 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

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 DISPLAY

- 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.

DOSE ALERT LEVELS

- 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

SUMMARY

- 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
  - In every appropriate CT study, the benefits outweigh the risks

imagegently.org
imagewisely.org

ACKNOWLEDGEMENTS

AAPM Working Group on Standardization of CT Nomenclature and Protocols

Co-Chairs
Cynthia McCoullough, PhD
Dianna Cody, PhD

ADULT HEAD – ROUTINE (HELICAL) (selected GE scanners)

SCOUT: Lateral, S150-I50. 120 kV, 10 mA. PA Scout optional.

GE	LightSpeed VCT	Discovery CT750 HD	LightSpeed VCT (w/ASIR)	Discovery CT750 HD (w/ASIR)
Scan Type	Helical	Helical	Helical	Helical
Rotation Time (s)	0.5	0.5	0.5	0.5
Detector Configuration	32 x 0.625	32 x 0.625	32 x 0.625	32 x 0.625
Pitch	0.531:1	0.531:1	0.531:1	0.531:1
Table Feed/Speed (mm/rot)	10.62	10.62	10.62	10.62
kV	120	120	120	120
mA	300	300	180 (DR 40%)	210
Auto-mA	no	No	no	no
SFOV	HEAD	HEAD	HEAD	HEAD
ASiR	no	No	SS40	SS50
Breath-hold	--	--	--	--
Prep Delay	--	--	--	--
CTDI-vol (mGy)	54.15	54.90	32.49	38.43
Recon 1				
Recon Start	Base of Skull	Base of Skull	Base of Skull	Base of Skull
Recon End	Vertex	Vertex	Vertex	Vertex
Plane	Axial	Axial	Axial	Axial
Algorithm	Stnd	Stnd	Stnd	Stnd
Recon Mode	Plus	Plus	Plus	Plus
Thickness (mm)	5	5	5	5
Interval (mm)	5	5	5	5
Recon 2				
Recon Start	Base of Skull	Base of Skull	Base of Skull	Base of Skull
Recon End	Vertex	Vertex	Vertex	Vertex
Plane	Axial	Axial	Axial	Axial
Algorithm	Bone	Bone	Bone	Bone
Recon Mode	Full	Full	Full	Full
Thickness (mm)	5	5	5	5
Interval (mm)	5	5	5	5